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AIR QUALITY ANALYSIS WORKSHOP

VOLUME I. MANUAL

ARGONNE NATIONAL LABORATORY

PREPARED FOR
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NOVEMBER 1975

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This material describes the air quality analysis system to be used for developing a control program for attaining and maintaining the National Ambient Air Quality Standards.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
State Implementation Plans Air Quality Maintenance Air Quality Analysis Control Program Development		

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AIR QUALITY ANALYSIS WORKSHOP
VOLUME I - MANUAL

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1-C

AIR QUALITY ANALYSIS WORKSHOP

VOLUME I – MANUAL

EPA-450/3-75-080-a

ERRATA

p. 15 — Table 3-1: The secondary annual standard for SO_2 (60 $\mu g/m^3$) should be deleted.

p. 51 — Section 3.3.6: The fourth line should read, "... especially the primary metals ..."

p. 113 — Problem 5-1: The seventh line should read, "... see Table D-9 ..."

p. 141 — Fig. 6-6: The bottom isopleth is 50 $\mu g/m^3$ instead of 75.

p. 156 — Table 7-1: The calculated air quality for receptor 233 in 1975 should be 77 $\mu g/m^3$ instead of 73, and the corresponding % reduction for primary standard should be 3% instead of "–."

p. 201 — Section 8.4.4, second paragraph: The seventh line should read, "... which is 90% of the county total."

p. 203 — Section 8.4.5: The fourth line should start with "day" instead of year.

p. 215 — Present Value Calculations: The ninth line should read, "... $E(1+i)^{-t}$, based on $E = C(1+i)^t$."

p. 216 — Equation 9-4: The term in brackets should be:

$$\left[\frac{1 - [(1+i)(1+e)]^{-t}}{(1+i)(1+e) - 1}\right]$$

Solution 3-2 — p. 5: The units for Gas, Qty should be 10^6 ft^3.

Solution 8-1 — p. 1: The approximate reduction in calculated concentration for stone quarry #2 at receptor 151 should be 1.38 (instead of 0.52) and at receptor 233 should be 0.77 (instead of 2.65). The reduction from stone quarry #3 at receptor 151 (0.69%) should be deleted. The total for receptor 233 should be 19 (instead of 21).

Solution 8-2 — p. 2: In step 3, the first equation should read, "$P_{1985} = P_o \times G_{1973,1985} \cdots$"

Solution 8-4 — p. 2: The last equation should have a "+" instead of a "–."

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1. INTRODUCTION

1.1 SCOPE AND OBJECTIVES

The development of an air pollution control strategy designed to attain and maintain the National Ambient Air Quality Standards (NAAQS) requires an analysis of current and possible future air quality problems. Previous publications[1-13] by the EPA Office of Air Quality Planning and Standards have been designed to provide guidance to regional, state, and local air pollution control and planning groups in the development of an analysis conforming to the requirements of the current federal regulations.[14] It is the objective of this workshop manual to illustrate, through the use of a ficticious county, some of the quantitative and qualitative procedures used in developing an acceptable plan.

Since it is not possible to incorporate the multitude of different situations that might influence the design of a NAAQS attainment/maintenance plan, this example of control strategy development is necessarily limited in scope. The major emphasis will be on the development of measures for the control of particulates since, of the 268 Air Quality Maintenance Areas designated,[15,16] all but a few have been identified as having particulate problems. Many of the procedures demonstrated here will be equally adequate for any of the other criteria pollutants (i.e., SO_2, NO_2, HC, CO, Oxidants) and the similarities and differences in the analysis will be noted accordingly.

This document likewise does not attempt to address the issues of how states or agencies affect intergovernmental cooperation, how states review and provide for public hearings on proposed plans, or how the mechanisms of plan submission and review are administered. The major emphasis in this volume is on the analytical procedures for the review and development of control options. In order to achieve a measure of realism in this exercise, the data for the ficticious county, "County X," have been based on Fulton County, Georgia. This choice was made due to the large volume of information previously compiled for this area.[13] In certain instances the data have been adjusted for the purpose of creating illustrative problems. Wherever possible, however, the form of the data, as it exists in reality, has been preserved, while only the numerical values have been changed.

It is not the purpose of this review to present new policy statements or to issue new guidelines for analytical procedures. Rather, it is designed to illustrate existing guidelines and to clarify the application of current policy. This document is specifically directed at providing working level state and local air pollution control engineers and planners with this guidance.

1.2 AIR QUALITY ANALYSIS OVERVIEW

Figure 1-1 presents a flow diagram of the Air Quality Analysis System (AQAS) procedure that will be reviewed here. The first step is to determine the level of analysis that is appropriate for the area under study. The objective of this step is to assure the most efficient use of available resources in control plan development. The next step is to compile a baseline data base consisting of air quality data, meteorological information, an air pollutant emission inventory, and regional planning data. This will form the foundation of the analysis. Next, growth and development information must be translated into indices to estimate future emissions. At this point, it may be necessary to revise the level of analysis detail to adjust to special problems identified by these estimates. The baseline and future emissions are then allocated to portions of the study area for the purpose of improving the spatial resolution of the analysis. Next, the air quality impact of the baseline and estimated future emissions are determined through the use of one of several available air quality simulation models. The modeling results are analyzed to determine the type and extent of the air quality problem present in the study area. At this point it may again be necessary to revise the level of analysis to properly treat the identified situations. Should the analysis indicate a NAAQS attainment and/or maintenance problem, then control strategies must be developed and tested through reapplication of the simulation model. After establishing a set of technically adequate control strategies, a final evaluation step should be performed to determine the relative effectiveness of each strategy in meeting the air quality goal. This final evaluation must account for known economic, social, legal, and institutional constraints as well as probable impediments to control strategy implementation.

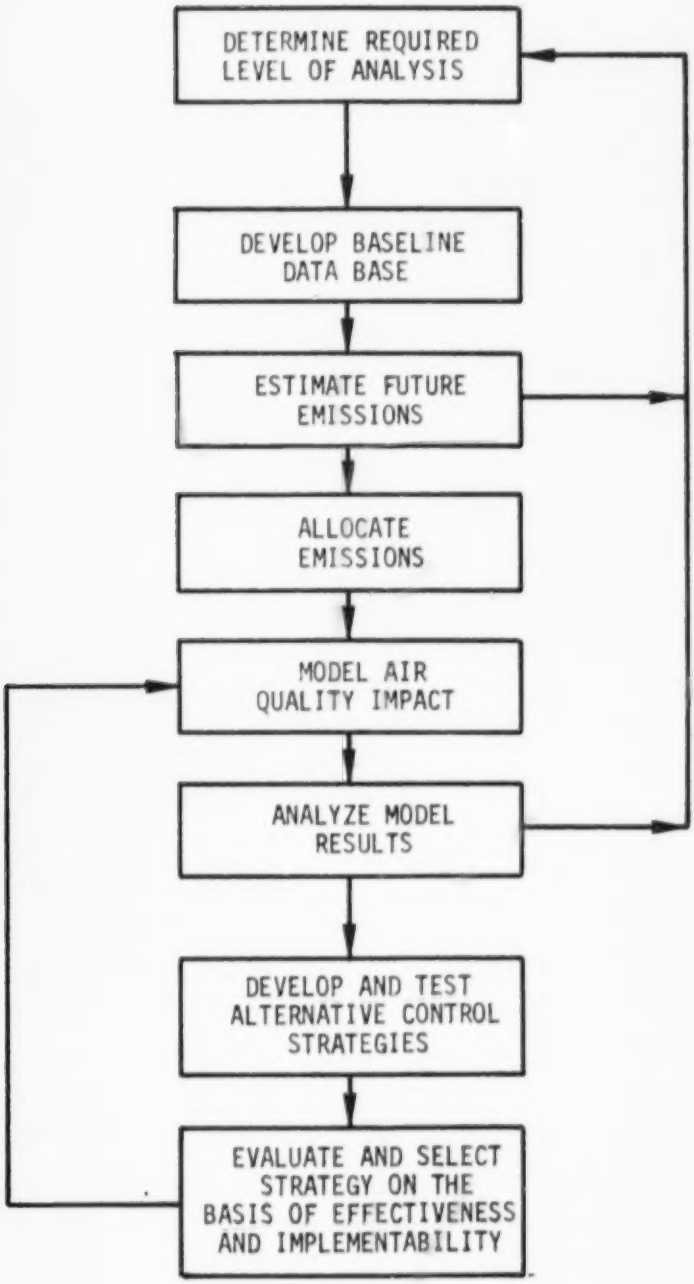

Fig. 1-1. Air Quality Analysis System

1.3 EXAMPLE COUNTY DESCRIPTION

1.3.1 Existing Conditions

County X, as shown in Fig. 1-2, is an elongated county, approximately 56 miles long and 14 miles wide with the long dimension oriented in a northeast-southwest direction. A river forms most of the western boundary, and the topography characterized by low hills and rolling terrain is not extreme.

Urban development dominates the central third of the county, in which the major city of the region and its contiguous suburbs are located. Little usable vacant land exists in the central portion of the urbanized area. The northern and southern thirds of the county are relatively sparcely populated, and less than 5% of the land in areas farthest removed from the center city is devoted to urban land uses (including residential, commercial, and industrial uses).

The largest concentration of commercial activity in the county occurs in the central business district (CBD) of the major city, with nearly 30% of the land area there in commercial use. The CBD is very close to the geographic center of the county. A few additional areas near the CBD also have appreciable commercial development, but clusters of commercial activity large enough to account for as much as 15% of the area of any census tract do not exist farther than about 12 miles from the CBD.

The CBD is also the location of appreciable industrial development. Additional industrial districts occur along railroads to the north, east, and southwest of the CBD. One of the major concentrations of large particulate point sources is in the industrial district about three miles north of the CBD in which a steel rolling mill, a grey iron foundry, and a lead smelting operation are located. Northwest of the CBD, between it and the river, is another significant industrial point source at the site of a brick and structural tile plant. A steam plant located in the CBD and another to the northwest are also large point sources of particulates.

Other industrial point sources beyond the boundaries of the county contribute to the particulate air quality levels over the region. Two coal, oil, and gas fired electric generating plants are closely spaced along the western bank of the river to the northwest of the CBD. Seven stone quarrying operations in neighboring counties form a ring of large particulate emitters

Fig. 1-2. Fulton County, Georgia - County X

around County X. These stone quarries account for more than half of the particulate emissions from point sources in the regional emission inventory.

One large area of predominantly residential development exists relatively near and to the west of the CBD. Suburbs to the north of the central city are primarily residential. Southwestern suburbs have a more diverse mix of urban land uses, but they too are the location of large areas of residential development.

1.3.2 Projected Development

The change in land use between the present and 1985 is typified by withdrawal of some land from urban use in the center of the built-up area, a significant increase in urban development in areas 8 to 10 miles from the CBD that currently are at the edge of the urbanized area (to the north, this rapid growth extends nearly 20 miles from the CBD), and a more modest trend toward urbanization in the northern and southern extremes of the county. While the total percentage of area devoted to urban land use in areas near the CBD appears to be in decline, a more significant trend is the increasing percentage of industrial land use in many of these same areas. Several of the existing industrial districts, in particular the area of foundries and smelting to the north of the CBD, show some decrease in activity, but nearby areas to the northeast and northwest of the CBD have the largest increases in industrial land use in the county. The moderate industrial activity that currently exists in the southeast corner of the urbanized central third of the county is another potential site of industrial expansion.

Residential land use more nearly follows the overall trend in urbanized land area, with reductions nearly universal in areas within 3 or 4 miles of the CBD. The actual locations of the growing residential areas are, in part, determined by the transportation network in the county and changes proposed for it. The completion of a new rail rapid transit system will result in much development activity near the terminals of its branches. Without further transportation investments, which is the assumption made here, this development will be clustered more densely about the terminals. The transit branches within the county extend only to the edges of the central third of the county, and overall growth, correspondingly, tends to be concentrated near the fringes of the current built-up area. Clusters of development, including sizable

increases in residential land use will be found by 1985 near the river to the west and northwest of the CBD and also approximately 12 miles to the southwest. Existing residential areas in the suburbs to the north will continue to more steadily northward, although these areas aren't well serviced by the new transportation system.

In summary, the anticipated increase of about 25% in population of the county up to 1985 will be accommodated somewhat less expansively than has been customary for metropolitan growth in the recent past.

2. DETERMINING LEVEL OF ANALYSIS DETAIL

2.1 OVERVIEW

The first step in the Air Quality Analysis System procedure is a determination of the required level of analysis detail (see Fig. 1-1). Ideally, the level of detail should be commensurate with the severity and extent of the existing and/or projected air quality problems. The unavailability of resources or data necessary to perform the analysis at the ideal level can limit the analysis to a less detailed level. The guiding concept should be that all analyses are to be carried out with the maximum reasonable effort.

During the analysis period it may be necessary to revise the estimates of the required level of analysis detail as the extent of the problems become more precisely defined and the limitations of available data and resources become clearer as indicated in Fig. 1-1. It is not possible to, a priori, define the detail required with complete accuracy. The level chosen must be a balance between the ideal of complete detail and what can be done within the available time with the available resources and data. This is often evident only after some experience with the analysis.

The basic steps in determining the level of analysis detail are outlined in Fig. 2-1. Three basic inputs determine the level of analysis:

Level of analysis appropriate to the air quality problems,
Limitations due to available resources, and
Limitations due to available data.

Prior to beginning the full AQAS procedure, some preassessment of these three inputs is necessary so that available resources can be used most efficiently.

It should be emphasized that the description of the process for determining the level of analysis detail is not intended to imply that this must be carried out as part of an acceptable Air Quality Maintenance Plan. It is designed only for the purpose of assisting the states in determining the best allocation of resources and need not be reported or referenced to in any plan submission.

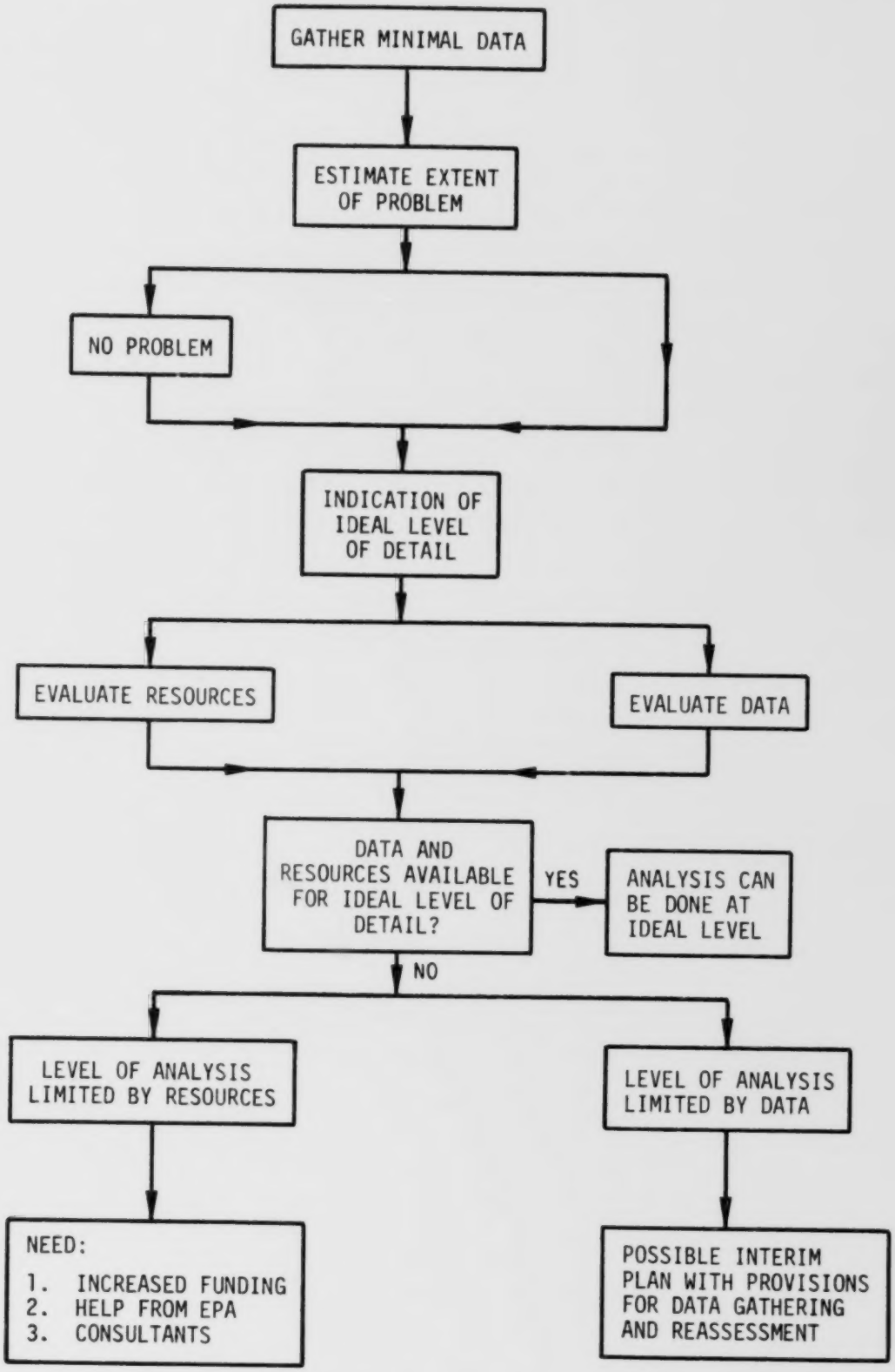

Fig. 2-1. Determining the Required Level of Analysis Detail

2.2 PREASSESSMENT

2.2.1 Gather Minimal Data

The preassessment phase consists of the initial completion of first five steps in Fig. 2-1. If reevaluation of the level of detail becomes necessary as the analysis progresses, the considerations given below would still apply, but the experience already gained during the analysis could be used to limit the reevaluation to those areas where a greater level of detail than was initially indicated would be needed.

The first step is to assemble some minimal data base that must include air quality data and the variables required for emissions projections. A minimal set of air quality data is available from the EPA's Storage and Retrieval of Aerometric Data (SAROAD) information file. Appendix A contains sample tabulations of the SAROAD data. Where more detailed air quality data are available at the state and local levels, it should be used, even in the preassessment phase, since it is important that the most severe problem be found. Several methods of making air quality estimates are discussed in Section 3 and may be used when actual data is unavailable.

The types of data needed to make emission projections are listed in Reference 7 and discussed in Section 4. The preassessment phase will generally be performed at a simple level of detail. Knowledge of local conditions may indicate that intermediate or full detail may be necessary for certain source categories or specific sources. If this type of a priori knowledge is available it can be used to avoid the duplication of effort involved in doing a simple analysis to confirm a result already established by experience. At a minimum, the emissions data from EPA's National Emission Data System (NEDS) are available. Appendix B contains some sample tabulations. Growth projections from the Office of Business Economics and the Economic Research Service (OBERS) are available at this stage. Appendix D contains this data for the Metropolitan Atlanta Air Quality Control Region (AQCR). Alternatively, a dialogue with local planning commissions may generate an insight into the growth prospects for the study area that would be usable for this preassessment.

Local knowledge and experience can, even in this initial phase, aid in guiding and limiting the data gathering efforts. Local air pollution control agencies will usually already have a reasonable estimate, based on

experience, what the major problems are and whether they are likely to be due to a few large point sources, numerous small area sources, or mobile sources. The preassessment of air quality data can also provide some guidance at this stage. If the data indicates severe and widespread problems, say areas more than about 20% above allowable levels, then it is likely that a complete analysis will be needed of suspect sources, and efforts to obtain the necessary data can begin early in the analysis process.

At this point a minimal data base has been collected and even before a formal estimate of the extent of the problem has been made, some focusing of the data gathering efforts has been made possible based largely on local experience. Efforts to obtain more detailed data can thus be continuing simultaneously with the first estimates of the extent of the air quality problem.

2.2.2 Estimate Extent of Problem

The most rudimentary type of air quality analysis is that based on subjective judgment or generalized procedures and criteria such as those used in the initial designation of Air Quality Maintenance Areas.[1] During the preassessment phase described here, a preliminary analysis at a simple level but more complete and reflective of local data is carried out. What is desired is a refinement of the indications of where problems will arise and what sources cause them by using readily available data.

Future air quality levels may be projected by using some form of atmospheric simulation model and rough approximations of future emission levels from the minimal data available. (Section 6 discusses the use of atmospheric simulation models.) If a sophisticated dispersion model (e.g., the Air Quality Display Model) is available and the agency performing the analysis has experience in its use, then it may be desirable to perform the preassessment with this tool. Otherwise, a simple proportional model will suffice for this phase. (Note that the modeling requirements described by the regulations[14] for the actual plan are not this slack.)

The preassessment analysis to determine the ideal level of detail can be structured by attempting to provide answers to the questions:

Is there an existing air quality problem?
Is there a maintenance (future) problem only?

What is the magnitude of the problem?
What is the spatial extent of the problem?
What types and categories of sources are involved?
How many sources are involved?

2.2.3 Indicate Ideal Level of Detail

With at least a partial answer to some of these questions, it is possible to determine what the most useful level of detail might be. For example, if the preassessment shows a particular source category to be creating a problem, then some effort should be expended in developing a detailed description of the emission patterns of sources in that category. If the preassessment shows projected air quality to be substantially in violation of the NAAQS, then substantial detail is required. If the preassessment shows air quality levels close to the NAAQS, detailed analysis is required to determine whether the projected problem is real. If the problem is a spatially localized "hot spot" problem due primarily to nearby sources, the greatest detail is necessary for these sources. Problems occurring throughout an analysis region require detailed information from the entire region. If problems occur in the future (beyond about 8 years) and more detailed data is needed, the time to develop the needed data bases is available. If the preassessments show no air quality problems, additional detail will still be needed to substantiate this projection.

2.3 EVALUATE RESOURCES

The available resources must be evaluated to determine the level of detail actually attainable. The steps are indicated in the left-hand branch on Fig. 2-1. The resource evaluation should examine:

The state of the present AQAS effort,
Level and expertise of staffing,
Existing plans affecting air quality,
Existing air quality management programs, and
Modeling capabilities.

Each of these parameters is examined for indications that it limits the level of detail obtainable to less than the ideal level. For example, there may not be enough personnel to perform the analysis at the ideal level. Much of

the required detail can already exist in the present State Implementation Plan, transportation control plan, or within other air quality programs such as new source review and variance programs. In other cases, the lack of experts in fields like transportation or planning may limit the level of detail. When the level of analysis detail is limited by resources, aid in increasing the level of detail obtainable can come from:

An increased level of funding,
Assistance provided by the EPA Regional Office, or
The use of consultants.

If these sources can provide no help, the maximum reasonable effort with the available resources must be put forth, knowing that the level of analysis detail will be less than ideal.

2.4 EVALUATE DATA BASES

Air quality projections depend upon several different data bases. The level of detail available in any base limits the level of detail at which the analysis can be done. The level of detail of the following data bases must be considered:

Air quality data,
Emissions inventory,
Growth factors and activity levels,
Transportation data, and
Allocation parameters.

The preassessment analysis will not use the most detailed data. It does indicate what level of detail is ideally needed in the data bases. If completely detailed data is available or can be made available within the limitations imposed by available resources, the air quality analysis can be done at the ideal level of detail. If sufficiently detailed data are not available, a detailed analysis cannot be done. It may be possible to prepare an interim plan using the best detail available with provision for gathering more detailed information. This would, of necessity, be followed by a reassessment of the problems. Otherwise, lack of data will limit the level of analysis to less than ideal.

3. DEVELOPMENT OF BASELINE DATA

The set of information required as a baseline for the development of an air quality analysis is made up of three parts: air quality data, meteorological information, and an emission inventory.

3.1 AIR QUALITY DATA

3.1.1 Uses of Data

Ambient air quality data are necessary for the development of attainment and maintenance strategies. Comparison of measured ambient levels or statistics computed from them with the National Ambient Air Quality Standards (NAAQS) is the primary means of determining whether air quality goals are being achieved. Where the NAAQS are being exceeded, the reason for the high levels must be determined and the need for corrective action evaluated. Comparison of data over a period of years for a specific area is an indicator of developing air quality trends. In areas exceeding the NAAQS, the trend can be used as a monitor of progress in attaining the standards. In areas where NAAQS are being met but where growth and development are occurring, upward trends in measured concentrations may dictate a reevaluation of the need for specific maintenance measures in addition to existing stationary source and mobile source programs.

In addition to the identification of current attainment and maintenance problems, projection of potential future problems and assessment of the effectiveness of present control strategies are based on ambient air quality data. When simulation models are used to either estimate present air quality at locations where no monitors exist or to predict future levels, air quality data should be used to calibrate the model. When proportional techniques of predicting air quality are used, air quality data are a necessary part of the calculations.

3.1.2 Estimation Methods and Averaging Times

In order to be compared with the NAAQS, air quality data must be available for the averaging times specified in Table 3-1. In addition, for averaging times less than one year, the data must include the second highest measured value since the NAAQS specify values "not to be exceeded more than once per year" for other than annual averages.

Table 3-1. National Ambient Air Quality Standards

Pollutant	Concentrations in $\mu g/m^3$ Averaging Time				
	1-hr	3-hr	8-hr	24-hr	1-yr
Particulates					
Primary				260	75 (G)
Secondary				150	60[a] (G)
SO_2					
Primary				365	80 (A)
Secondary		1300			60 (A)
CO	40[b]		10[b]		
Hydrocarbons		160[c]			
Oxidants	160				
NO_2					100 (A)

[a] Intended as a guide to meeting the 24-hour secondary standard (40CFR50).

[b] CO concentrations measured in mg/m^3.

[c] 6 AM to 9 AM only. The hydrocarbon standard is intended as a guide to achieving the oxidant standard.

(A) Arithmetic average.

(G) Geometric average.

NOTE: All averages less than 1 year are not to be exceeded more than once per year.

When data for the averaging times specified in the NAAQS are not available, the following situations arise:

> For continuous data where the hourly averages are available, the appropriate averages and second highest values may be calculated.
>
> For non-sequential data, for incomplete data sets, and for data where only summary statistics are available, the appropriate averages and second highs may be estimated using Larsen's statistical methods.[17,18]

In using continuous data, References 11 and 19 may be consulted to determine how to average data and compute second highest values. In particular, it should be noted that:

> The running average beginning at each clock hour should be used for the short-term standards, and
>
> The maximum second highest non-overlapping value should be used for standards not to be exceeded more than once per year.

It should be emphasized that only measured data can be used to evidence violations of the NAAQS; Larsen's methods can, however, be used to estimate the severity of existing or future air quality problems.

Frequently aerometric data is only available in summary form giving some of the following information:

> Annual arithmetic mean,
>
> Annual geometric mean,
>
> Standard deviation,
>
> Geometric standard deviation,
>
> The total number of samples and the maximum measured value, or
>
> Two percentiles and the corresponding concentration values.

If any pairs of these except the third and sixth or fifth and sixth is available, Larsen's methods can be used to:

> Estimate the concentration likely to be exceeded more than once per year for comparison with the NAAQS, and/or
>
> Use data available for one averaging time to estimate the statistics appropriate to another averaging time.

Larsen also describes a simple graphical method that can be used to estimate the concentrations that are exceeded with a particular frequency when the geometric mean and geometric standard deviation are known. This graphical technique can be used in the simplest level of analysis as a quick means of estimating the values that are exceeded more than once per year.

The validity of Larsen's techniques depends upon how closely the actual data fit the model's assumption that air quality data are lognormally distributed. Unless past experience has shown that Larsen's methods are valid for the pollutant and in the area of interest or unless the individual measured values are available to test for lognormality, his methods must be used with some caution. The test for lognormality can be made either graphically by seeing whether the data fall approximately on a straight line when plotted on log-probability paper, or analytically by use of the statistical χ^2 test.

Larsen's methods were based on data taken at Continuous Air Monitoring Program (CAMP) sites in urban locations and would be expected to be applicable in similar locations. They should not be applied in areas dominated by single strong point sources. If the critical assumption of lognormality cannot be tested because only summary statistics are available, then a complete set of individual measurements should be collected to establish the applicability of Larsen's methods.

If the data prove not to be lognormal or if past experience has shown Larsen's methods inappropriate, there are nonparametric statistical tests that do not require the assumption of lognormality. Reference 19 discusses one simple test that can be used to infer whether a certain quartile of a complete data set would exceed a specified value when only a sample of the set is available. The assistance of a trained statistician should be sought when dealing with these problems.

3.1.3 Spatial Distribution of Sites

The spatial distribution of sites with air quality data is also important. EPA regulations for State Implementation Plans require a minimal number of monitors in each Air Quality Control Region (AQCR), but this number is usually too small to provide a detailed assessment of ambient air quality. General guidance in assessing the coverage provided by a monitoring network is provided in References 11 and 19. Ideally, data should be available from:

Hot spots where concentration maxima occur,

Clean areas that can be used to estimate background concentrations,

Areas with the highest population density or total population,

All distinct subareas of the region of interest,

Areas where rapid growth and development are expected,

Areas projected to have the highest future concentrations.

Comprehensive data of this type will generally be lacking and modeled estimates of air quality at various locations will be necessary. In an urban area, about twenty points provide reasonable confidence in a model calibration. Frequently, however, fewer will be available and correspondingly less confidence can be placed in the accuracy of modeled air quality estimates. Since air quality maintenance considerations have not been primary in monitoring network design, data from areas where rapid growth and development are expected and areas projected to have the highest future concentrations are likely to be unavailable. In addition, identification of these areas would emerge only as the air quality analysis process progresses. Expansion of the monitoring network to provide more comprehensive coverage is thus likely to be necessary, especially in areas with anticipated air quality problems.

3.1.4 Time Distribution of Data

When baseline data sets are being gathered, the time period covered and the number of observations at each site must also be considered. Data must be available from the appropriate baseline year and all the data must be from the same year. Since most monitoring programs are expanding, the most recent available year of data will probably be the most comprehensive. The air quality data year must also correspond to the emission inventory year used to calibrate a dispersion model and make projections for attainment and maintenance planning.

3.1.5 Evaluation of Data

Some evaluation of the data should also be done where possible. In References 11 and 19, EPA has provided methods of evaluating the acceptability of air quality data when the full data sets are available. For example, oxidant data taken at night and carbon monoxide data taken during early morning hours are likely to be unrepresentative of potential problems, since the maximum concentrations of these pollutants generally occur at times of high insolation and peak traffic density, respectively. Where non-sequential sampling schedules

have been used, the number of samples can be used to estimate the precision of calculated means by the methods of Hunt.[20] Proposed amendments to EPA's requirements for the submission of state implementation plans allow consideration of the accuracy and precision of data and projections in determining whether NAAQS will be attained and maintained. The effect on projected air quality concentrations of factors such as the following may be considered:

> Current air quality concentrations,
>
> The magnitude of past year-to-year variations in air quality concentrations, and
>
> The degree of confidence in the methods used to determine air quality concentrations resulting from projected emissions.

The number of samples in a year's data set also indicates whether the set can be considered complete. If, for example, there are only 2,000 hourly sulfur dioxide values in a data set for a year, the data set should probably be rejected in accordance with the guidelines that require 75% of the possible values to be present before statistics are computed.

3.1.6 Method of Measurement

One further consideration must be given to the data. Only data collected by certain methods can be used as the basis for air quality analysis and planning. A summary of approved, unapproved, and unacceptable methods is given in Table 1 in Reference 11. Unapproved methods are currently employed in many places and for SO_2, CO, and oxidants. They may continue to be used until a federal reference method has been promulgated. For methods not listed in the table as, for example, sulfation methods of measuring sulfur dioxide, the EPA Regional Office should be consulted concerning the acceptability of the data.

3.1.7 Sources of Data

State and local air pollution control agencies will usually be the best sources of air quality data, as they generally have the most complete and recent data sets. A portion of the state and local data is also submitted to EPA through its Regional Offices. This data is stored in the SAROAD

(Storage and Retrieval of Aerometric Data) system from which it can be accessed in reduced data format through the Regional Offices. Submissions to SAROAD are filtered at both the regional and national levels. Hence, state and local agencies usually have more detailed and comprehensive data than is available from SAROAD. Proposed EPA regulations would require that all applicable air quality data collected since October 1, 1972, be used in the analysis and that such data be submitted to SAROAD so that the plan can be evaluated and future progress assessed.

Agencies at all levels sometimes conduct special short-term sampling programs aimed at the evaluation of specific problems. When baseline air quality is being established, data from such programs can often provide information supplementing the more comprehensive data obtained from other sources.

In areas where measured air quality data is lacking, two methods are available to estimate expected levels:

Dispersion modeling, and
Estimates based on measured air quality in similar areas.

Reference 12 discusses the air quality simulation models generally available, their capabilities, and their data requirements. Anticipated amendments to Appendix A Air Quality Estimation[14] will provide explicit guidance as to which models shall be used in developing State Implementation Plan revisions. When measured air quality data are unavailable, the model is used uncalibrated; that is, modeled air quality concentrations are not compared to actual measured air quality data and hence the modeled results must be regarded as approximations until a monitoring program can be established, data collected, and the model predictions compared with actual measured values.

If measured data are available from areas with emission densities, meteorology, topography, and source types similar to those in the area of interest, these data may be used as indications of expected air quality in the area of interest. Such estimates would not account for hot spots caused by large point sources, such as power plants. Any large sources would have to be modeled separately. If this method is used, it is essential that confirmation of the estimates be made through an expanded monitoring program.

3.1.8 Illustration of County X Data

Figure 3-1 shows one of the SAROAD printouts for total suspended particulates from a high volume sampler site in County X. Air quality data for County X was obtained from similar printouts which give:

The cumulative frequency distribution,
Number of observations,
Measured maximum and minimum,
Arithmetic mean (average),
Geometric mean,
Geometric standard deviation,
Various other information including site name, UTM coordinates, and other locational information.

The NAAQS for particulates are listed on Table 3.1. Since there are two 24-hour particulate standards not to be exceeded more than once per year and since the actual second highest value is not given in the data set, some method must be used to estimate whether the short-term standards are being attained. If the actual second highest measured value is available, it would be sufficient to use this value in the analysis although such a procedure usually underestimates the severity of the short-term problem if data is available for less than about one third of the days (see Reference 11). More than a sufficient amount of information is available on the printout to employ Larsen's methods. The graphical and two analytical methods will be illustrated.

Graphical Method In Fig. 3-2, Larsen's methods have been used to estimate the highest and second highest 24-hour values for comparison with the standards by the graphical method using log-probability paper. Only the geometric mean and the geometric standard deviation are needed to plot the line. The geometric mean plots as the 50% point on the graph. Using the geometric standard deviation, the value to be plotted at the 16% point (C_{16}) can be found from

$$C_{16} = \text{(geometric mean) X (geometric standard deviation)} \qquad (3\text{-}1)$$

where C_{16} is the concentration that is expected to be exceeded 16% of the time. These two points can be plotted and a "Larsen line" drawn through them as in Fig. 3-2. As an aid in drawing the line, a third point may be plotted:

NATIONAL AEROMETRIC DATA BANK
YEARLY FREQUENCY DISTRIBUTION
STATE (11): GEORGIA

11

SITECODE: 110200042
AGENCY/PROJECT: 002
AGENCY TYPE: COUNTY
CITY POPULATION: 496,973
AGCR POPULATION: 1,714,336
EPA-REGION: 4
SUPPORTING AGENCY: FULTON COUNTY HEALTH DEPT AIR POLLUTION CONTROL SECTION
COMMENTS: CHATTAHOOCHEE WATER TREATMENT PLANT CORNER BOLTON RD & MARIETTA BL

LOCATION: ATLANTA
COUNTY (22600): FULTON CO
SITE ADDR: 2532 BOLTON RD
STATION TYPE (21): SUBURBAN - INDUSTRIAL
AGCR (0560): METROPOLITAN ATLANTA
SMSA (10520): ATLANTA, GEORGIA

LATITUDE: 33 D. 49 M. 20 S. N
LONGITUDE: 84 D. 27 M. 10 S. W
UTM ZONE: 16
UTM NORTHING: 3745200
UTM EASTING: 00735750
ELEVATION ABOVE GROUND: 027 FT.
ELEVATION ABOVE MSL: 0820 FT.
DIFF. GMT: WEST 05 HOURS

YEAR	POLLUTANT / POLLUTANT-METHOD CODE / METHOD / INTERVAL AND UNITS	NUM OBS	MIN OBS	10	30	50	70	90	95	99	MAX OBS	ARITH AVG	GEOMETRIC MEAN	GEOMETRIC STD DEV
74	PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	55	17.	20.	46.	58.	77.	109.	140.	181.	181.	66.	57.73	1.72
75	PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	24.	25.	35.	60.	70.	105.	124.	124.	124.			

Fig. 3-1. Annual SAROAD Frequency Distribution for TSP Data

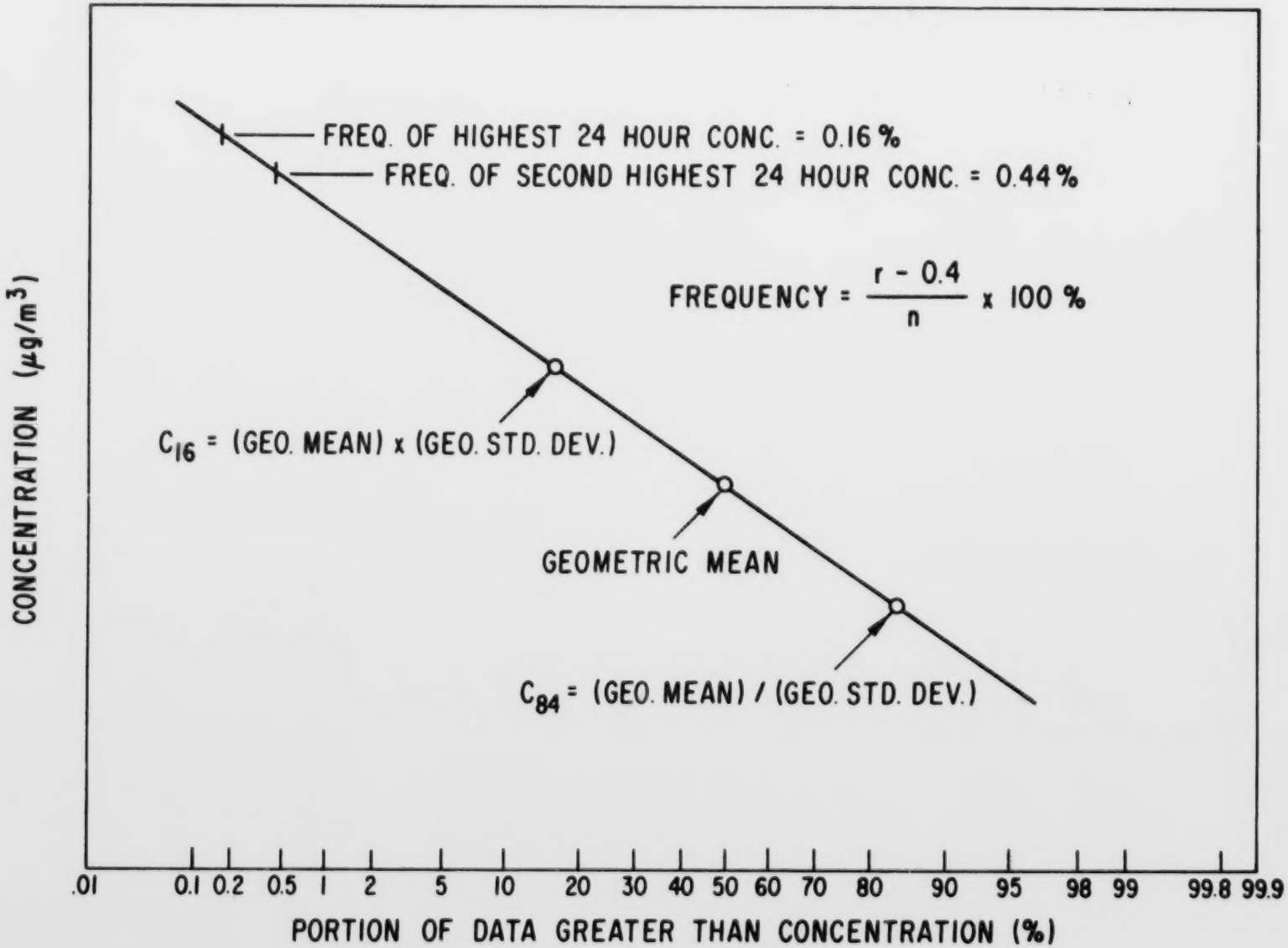

Fig. 3-2. Use of Larsen's Method to Estimate Air Quality

$$C_{84} = \text{(geometric mean)/(geometric standard deviation)} \qquad (3\text{-}2)$$

where C_{84} is the concentration that is expected to be exceeded 84% of the time.

The measured frequency distribution should lie along this line if the data is lognormally distributed. Since Larsen lines are usually plotted so that a frequency-concentration pair gives the percentage of data greater than that concentration while the SAROAD printout pairs give the percentage of data less than the corresponding concentration, the Pth percent point on the SAROAD printout plots as the (100 - Pth) percent point for comparison with the Larsen line.

To estimate the two highest expected concentrations, the frequencies for the highest and second highest values for a year must be calculated. Larsen uses a correction term and the formula:

$$f = \frac{r-0.4}{n} \times 100\% \qquad (3\text{-}3)$$

where f = plotting frequency (%), r = rank order (highest, second, third, ...), and n = the number of samples.

For a year of 24-hour samples, n = 365. The highest expected concentration would occur at a frequency of:

$$f_{highest} = \frac{1-0.4}{n} \times 100\% = 0.16\% \quad \text{and} \qquad (3\text{-}4)$$

the second highest or second most polluted (SMP) day would occur at a frequency of:

$$f_{SMP} = \frac{2-0.4}{365} \times 100\% = 0.44\%. \qquad (3\text{-}5)$$

<u>Analytical Procedures</u> The primary annual standard of 75 $\mu g/m^3$ is apparently being met at the site tabulated on Fig. 3-1, since the measured average is 58 $\mu g/m^3$. Hunt's method[20] can be used to place a confidential interval around this value. For lognormally distributed data, Hunt gives:

$$M1 = 1-\exp(-t \frac{S}{\sqrt{n}} \sqrt{(1-\frac{n}{N})}\ ) \text{ and} \tag{3-6}$$

$$M2 = \exp(t \frac{S}{\sqrt{n}} \sqrt{(1-\frac{n}{N})}\ ) - 1, \tag{3-7}$$

where S = ln (geo. std. dev.) = ln 1.72 = 0.5423, n = number of samples = 55, N = number of possible samples = 365, t = the "t-statistic" for n-1 degrees of freedom and the chosen confidence level, and M1 and M2 are the distances between the lower and upper confidence limits, respectively, expressed as a fraction of the measured geometric mean.

If we want 95% confidence limits, the value of t for 54 degrees of freedom (available in standard statistical tables) is about 2.00. Using this value:

$$M1 - .1263 \text{ and } M2 - .1446. \tag{3-8}$$

With a confidence of 95% it can be said that the true geometric mean lies between:

$$\begin{aligned} 57.72(1-.1263) &= 50\ \mu g/m^3 \text{ and} \\ 57.72(1+.1446) &= 66\ \mu g/m^3. \end{aligned} \tag{3-9}$$

Thus, there is a reasonable assurance that even had a full set of 365 daily readings been available, this site would not have violated the primary annual standard, since even the upper 95% confidence limit of 66 $\mu g/m^3$ is well below the standard of 75 $\mu g/m^3$.

The short-term analysis can also be done analytically. The method to be used depends upon the data available. If the geometric mean and geometric standard deviation are available, Larsen gives a simple equation to estimate the second most polluted (SMP) day in Reference 18. His formula is:

$$C = MgSg^z \tag{3-10}$$

where C = the required concentration, Mg = geometric mean, Sg = geometric standard deviation, and z = distance of C from the mean measured in standard deviations.

Inability to find z often deters the use of Larsen's analytical formulas. The following simple method permits the calculation of z:

1. Find f from the formula for frequency used in the above graphical analysis, but express the result as a decimal rather than as a percentage:

$$f = \frac{r-0.4}{n}$$

2. Find $U = [\ln(1/f^2)]^{1/2}$.

3. Then $z = U-(2.52 + .8U + .01U^2)/(1.0 + 1.43U + .19U^2 + .001U^3)$.

In this analysis for the SMP value, r=2 and there would be n=365 samples in the year.

$$f = \frac{2-0.4}{365} = .0043835$$

$$U = 3.2954 \qquad (3\text{-}11)$$

$$z = 2.62$$

The SMP value can then be estimated:

$$C_{SMP} = 57.72(1.72)^{2.62} = 239\ \mu g/m^3. \qquad (3\text{-}12)$$

This is in good agreement with the 235 $\mu g/m^3$ value estimated from the graph and certainly within the limits of expected error in drawing the Larsen line and interpolating values.

A second frequently available set of information is the actual number of samples n(=55 in this case), the <u>arithmetic</u> mean m(=66 $\mu g/m^3$), and the maximum measured value C_{max}(=181 $\mu g/m^3$). The frequency appropriate to the observed maximum and the corresponding z can be found as above:

$$f = \frac{r-0.4}{n} = \frac{1-0.4}{55} = 0.019090, \text{ and}$$

$$z = 2.2939. \qquad (3\text{-}13)$$

Equation (34) in Reference 17 can then be used to find Sg:

$$
\begin{aligned}
Sg &= \exp(z-[z^2-2\ \ln(c/m)]^{0.5}) \\
&= \exp(2.2939-[2.2939^2-2\ \ln(181/66)]^{0.5}) \qquad (3\text{-}14) \\
&= 1.6367
\end{aligned}
$$

Finally, Equation (22) in Reference 17 can be used to estimate the SMP value using the Sg value of Equation (3-14) and the SMP z value of Equation (3-11):

$$
\begin{aligned}
C &= m\ Sg^{(z-0.5\ \ln\ Sg)} \\
C_{SMP} &= 66(1.6367)^{(2.62-0.5\ \ln\ 1.6367)} \qquad (3\text{-}15) \\
&= 213\ \mu g/m^3
\end{aligned}
$$

This result is somewhat less than the estimates obtained by the other two methods but is still within the expected degree of precision. This last method depends heavily on the value of the highest measured value, a value that can frequently be somewhat in error. The method using the geometric mean and geometric standard deviation is preferable, since it makes full use of all the data and is computationally simpler.

In conclusion, the area around this site could well be exceeding both short-term TSP standards but probably not the annual standard. An increase in the number of samples per year at the site would allow a better definition of the potential short-term problem and should be undertaken. Modeling should help to better define the extent of the current attainment problems, if any, and to determine the contributions of various categories of sources to the problem.

One further consideration should be given to the data from this site. High volume samplers are required to run at least every sixth day, giving 60 or 61 samples per year. There are only 55 samples from this site. However, there are over 75% of the minimum required number of samples and statistics can be computed. Figure 3-3 shows the SAROAD frequency distribution by quarters for this site. The five "missing samples" belong in the first quarter of the year when only 10 samples were recorded. However, every quarter is represented by an adequate number of samples and the set is probably representative of the TSP situation at the site for 1974.

10-02-75

NATIONAL AEROMETRIC DATA BANK
QUARTERLY FREQUENCY DISTRIBUTION
STATE (11): GEORGIA

11

SITECODE: 110200042
AGENCY/PROJECT: G02
AGENCY TYPE: COUNTY
CITY POPULATION: 496,973
AQCR POPULATION: 1,719,336
EPA-REGION: 4
SUPPORTING AGENCY: FULTON COUNTY HEALTH DEPT AIR POLLUTION CONTROL SECTION
COMMENTS: CHATTAHOOCHEE WATER TREATMENT PLANT CORNER BOLTON RD & MARIETTA BL

LOCATION: ATLANTA
COUNTY (2260): FULTON CO
SITE ADDR: 2532 BOLTON RD
STATION TYPE (21): SUBURBAN - INDUSTRIAL
AQCR (0561): METROPOLITAN ATLANTA
SMSA (0520): ATLANTA, GEORGIA

LATITUDE: 33 D. 49 M. 20 S. N
LONGITUDE: 84 D. 27 M. 10 S. W
UTM ZONE: 16
UTM NORTHING: 3745200
UTM EASTING: 00735750
ELEVATION ABOVE GROUND: 027 FT.
ELEVATION ABOVE MSL: 0820 FT.
DIFF. GMT: WEST 05 HOURS

YEAR-QUARTER POLLUTANT / POLLUTANT-METHOD CODE / METHOD / INTERVAL AND UNITS	NUM OBS	MIN OBS	PERCENTILES 10	30	50	70	90	95	99	MAX OBS	ARITH AVG	GEOMETRIC MEAN	STD DEV
74-01 PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	10	18.	18.	60.	71.	95.	109.	173.	173.	173.	83.	72.27	1.84
74-02 PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	30.	35.	43.	57.	69.	98.	181.	181.	181.	65.	58.13	1.59
74-03 PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	17.	20.	26.	47.	56.	106.	109.	109.	109.	51.	43.69	1.81
74-04 PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	32.	38.	54.	59.	86.	125.	140.	140.	140.	71.	65.24	1.55
75-01 PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	24.	25.	35.	60.	70.	105.	124.	124.	124.	59.	52.30	1.69

Fig. 3-3. SAROAD Frequency Distribution by Quarter for TSP Data

PROBLEM 3-1

Given the SAROAD printout (Fig. 3-1) and the outline of Larsen's graphical method, use log-probability graph paper to determine whether it is reasonable to expect a short-term particulate problem at this site. Are there any indications that Larsen's methods are not applicable at this site? Determine if the data are lognormally distributed.

3.2 METEOROLOGY

3.2.1 Uses of Data

Baseline data defining the meteorology of the region must also be collected. This data is needed to:

Input to dispersion models,

Identify the frequency and duration of conditions when short-term, high air pollution levels can exist, and

Estimate fuel consumption for and emissions from space heating.

With the exception of proportional techniques, all models used to relate emissions to air quality require meteorological input whose level of detail depends upon the specific model employed. Unless scaling or statistical techniques, such as Larsen's method, are used, comparison of modeled air quality levels with short-term standards requires the identification of the frequency and duration of short-term periods when meteorological conditions conducive to high pollution levels exist. The methods commonly used to estimate fuel usage for space heating require that the number of "degree days" be known. This parameter is a necessary input for the methods used in Reference 7 to develop emission inventories.

3.2.2 Data Required

The meteorological parameters required include:

Wind speed,
Wind direction,
Atmospheric stability,
Mixing height,
Temperature,
Pressure,
Solar radiation intensity,
Cloud cover,
Ceiling height, and
Degree days.

Which of these parameters are required depends upon the level of detail of the analysis employed and the model to be used. A list of the meteorological inputs required by the various models available from EPA is given in Reference 12.

Requirements vary from no meteorological input for proportional techniques to hourly variations of wind direction, wind speed, stability, and mixing height.

Wind Speed, Wind Direction, and Atmospheric Stability The National Climatic Center (NCC) in Asheville, North Carolina has wind speed and wind direction data available as part of hourly or three-hourly weather records. This data is also frequently available locally from measurements made by state or local air pollution control agencies or from airports.

Data for wind speed and wind direction are frequently combined with atmospheric stability in a joint frequency distribution called a stability wind rose. Various stability wind roses are available from NCC in tabular form, on punched cards, and on tape. The tapes include the hourly or three-hourly observations upon which the stability wind rose is based. Five-year, annual, seasonal, and monthly stability wind roses are available. These stability wind roses are the primary meteorological inputs required by the common dispersion models for annual averages.

Mixing Height Holzworth[21] has provided climatological summaries of mixing heights based on radiosonde observations. He presents isopleth maps of the United States giving morning and afternoon mixing heights on a seasonal and annual average basis. The isopleths for annual average afternoon mixing height (required for the AQDM model) are presented on Fig. 3-4. Mixing heights can be calculated from the radiosonde observations available from NCC by the methods outlined in Reference 10. The calculations are, however, laborious and it is preferable to use Holzworth. If daily morning and afternoon mixing heights are needed, it may be possible to obtain them from a nearby weather station or meteorological data center. Otherwise, the calculations based on other meteorological parameters must be made.

Temperature and Pressure Temperature and barometric pressure data are needed in the calculation of plume rise. NCC can supply the data. In addition to the hourly and three-hourly temperature records, various summaries, some of which are listed in Reference 10, are available. Since variations in temperature and pressure cause only small changes in calculated ground-level concentrations, most calculations simply use the annual mean values

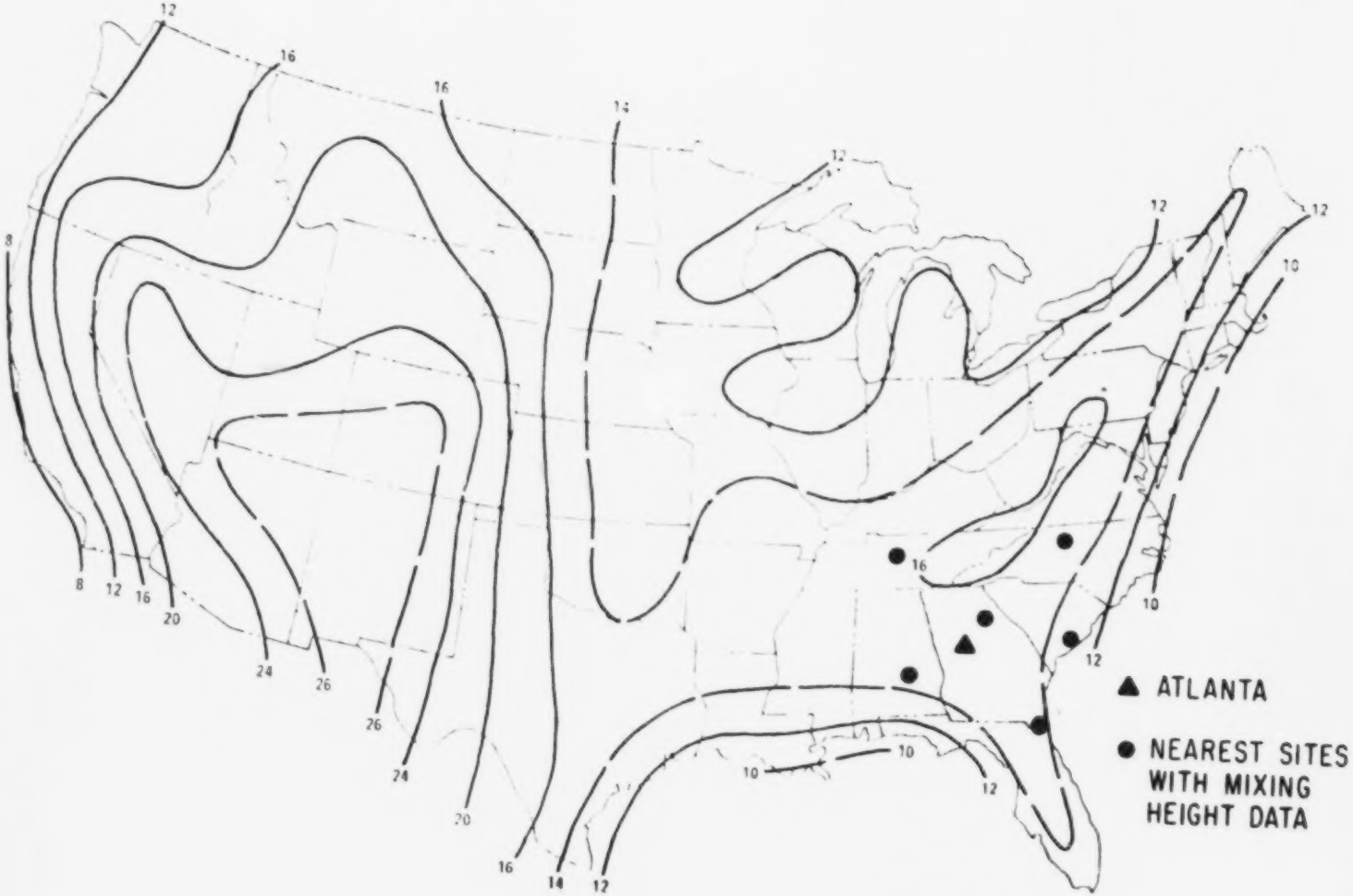

Fig. 3-4. Isopleths (m x 10^2) of Mean Annual Afternoon Mixing Heights

from the nearest weather station. Barometric pressure is also available from NCC in annual average form as well as the hourly or three-hourly observations.

Solar Radiation Intensity, Cloud Cover, and Ceiling Height If atmospheric stability data are unavailable, they may be estimated from other meteorological parameters by Turner's method,[22] which is also explained in Reference 10. The method requires: solar altitude, cloud cover, ceiling, and wind speed. The solar altitude can be obtained from Table 170, Solar Altitude and Azimuth, in the Smithsonian Meteorological Tables.[23] Cloud cover and ceiling are available as hourly or three-hourly observations from NCC. The solar altitude, time of day, cloud cover, and ceiling can be used to index the solar radiation intensity that, together with the wind speed, determines the atmospheric stability. Turner[24] has also presented another method of determining stability based on the same meteorological observations but not requiring the ceiling. When a stability wind rose from NCC can be used, the stability has already been determined and is available on the tape at hourly or three-hourly intervals.

Degree Days Heating degree-days are used to estimate fuel consumption for space heating. The number of degree-days is determined from the number of days the average daily temperature drops below 65°F. For example, a day with an average temperature $\left(\frac{\text{high temperature} + \text{low temperature}}{2}\right)$ of 64°F counts as 1 degree-day; a day with an average temperature of 50 degrees counts as 15 degree-days. The data are available from NCC or Reference 39.

3.2.3 Worst Case Data

It is generally assumed sufficient for predicting annual average concentrations to use a stability wind rose for a typical year or one representing an average over several years rather than to attempt to identify those meteorological conditions causing the highest possible annual average. A sensitivity analysis comparing modeled air quality concentrations for stability wind roses from several years, while keeping the emissions inventory constant, allows an estimate to be made of the variations expected from changes in the weather alone. Such an analysis could be used in the discussion of factors affecting the accuracy of the calculations of projected air quality concentrations.

For the 3, 8, and 24-hour standards, the situation is more complex, since the persistence in time of conditions giving rise to high concentrations must be determined. If short-term concentrations are modeled, two methods can be used to determine a reasonable estimate of short-term worst-case conditions:

Consultation with an air pollution meteorologist, and/or

A review of past meteorological records to determine what conditions have led to high concentrations.

In situations where short-term concentrations are to be modeled by repetitive application of a model for each hour, consultation with an experienced air pollution meteorologist, particularly one who has knowledge of the local situation, offers perhaps the best chance of determining what conditions, consistent with local meteorology, would constitute a worst case. Otherwise a search of air quality and weather records to determine the conditions associated with high pollution levels must be made. Meteorological records are generally available over a longer time than air quality records, so after the weather conditions associated with high pollution levels have been determined, the search for a worst historical case can be carried back through the available years of meteorological data. Such a procedure is complicated by fact that the concentration levels are also dependent upon emissions. Some sensitivity analysis should be carried out to investigate the effect of changes in the meteorological input on predicted concentration levels. If the predicted levels do not change significantly for various estimates of worst-case conditions, then finding the true worst case meteorology is probably not important. If, however, the predicted levels are significantly dependent upon the assumed worst case meteorology, the accuracy of the predicted air quality results is questionable, since the true worst case can only approximated by this procedure. In making this assessment, changes in concentration levels are significant if they are on the order of the changes expected due to errors in the other input variables. For example, if a change in the mixing height from 1000 m to 1500 m produces only a one or two percent change in predicted concentration levels and larger errors, say 8-10%, could be caused by suspected inaccuracies in the emission inventory, an attempt to determine precisely what series of hourly mixing heights constitutes a worst case would unnecessary.

3.2.4 Representativeness of Data

Two problems frequently arise when gathering meteorological data:

The data has been taken at a site remote from the expected problem area, and

The site for which data exists is not similar to the problem area.

Meteorological data is often frequently available only from local airports that are generally located in rural or semi-rural areas. If the problem area is urban, there may be differences between the values measured at the airport and those appropriate to the urban area. This is particularly true of temperature, wind speed, mixing height, and stability, which are affected by the urban heat island and the difference in surface roughness between rural and urban areas. As another example, mixing heights are calculated from soundings taken at points on a grid of approximately 400 km, and hence their spatial resolution is limited. Also, the data may be available from a site on a hilltop, while the expected problem area is in a valley.

Two courses of action can be followed when representative meteorological data is unavailable:

Adjust existing data, or

Use data from the closest similar site.

In both cases, a meteorologist should be consulted either to suggest ways of adjusting the data or to help choose among candidate sites if more than one is available. This person could also aid in the assessment of the probable errors resulting from the adjustment of the data or from use of data at another site. If there is some limited data available from the problem area, it may be possible to develop a relationship between values or averages at the problem site and those measured at the remote site. Such a relationship could then be used to estimate values for the problem area from the more extensive records at the remote or dissimilar site. A meteorologist may be able to suggest alternative ways of adjusting data as, for example, rotating or compressing wind roses to account for the effects of local topography.

In some cases, the data on file with the National Climatic Center is incomplete or represents only a short observation period (e.g., one or two

years). In these cases, the same option of adjusting existing data or using more complete data from another site would have to be exercised.

3.2.5 Illustration from County X Data

In Fig. 3-5, the part of the stability wind rose for County X for C stability is presented as it comes in printed format from NCC. The entries in the table give the relative frequency under conditions of C stability with which winds from sixteen different directions occurred within six different speed categories. For example, conditions of C stability with south-southeast winds between seven and ten knots occur .002260 or 0.2260% of the time in County X. The stability wind rose data in this format was used to punch cards as input to the AQDM model used for County X.

The stability wind rose is based on data taken at the Atlanta International Airport. Figure 3-6 shows the outline of County X and the location of the airport. The airport is located close to the portion of the county that is an area of low rolling hills. No attempt was made to change any of the wind rose data to correct for topographic effects.

Atlanta is located by the dot on Holzworth's map of afternoon mixing heights on Fig. 3-4. It lies midway between the 1400 m and 1600 m isopleths and 1500 m was used as the input to the model. The nearest stations where data upon which the isopleths were based are also shown. Since these are relatively far from Atlanta, the representativeness of the 1500-m value might be questioned. However, substitution of 900 m for the mixing height produced less than a 2% change in modeled TSP concentrations and hence, within the accuracy to be expected from the model itself, the value assumed for the mixing height is not critical over this range. From the isopleths it seems unlikely that a lower mixing height would be appropriate, particularly since Atlanta is not located in a deep valley where greatly reduced mixing heights can occur.

3.3 EMISSION INVENTORY

The air pollutant emission inventory forms the basis of making an assessment of air quality management problems. Substantial guidance in the development of an emission inventory has already been published.[7,13,25]

ANNUAL RELATIVE FREQUENCY DISTRIBUTION STATION =13874 ATLANTA,GA 67-71

SPEED(KTS)

DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.000624	0.002603	0.003562	0.000274	0.000000	0.000000	0.007063
NNE	0.000170	0.001370	0.000685	0.000000	0.000000	0.000000	0.002225
NE	0.000195	0.000685	0.001233	0.000000	0.000000	0.000000	0.002113
ENE	0.000263	0.001644	0.002123	0.000411	0.000000	0.000000	0.004441
E	0.000541	0.002466	0.006781	0.001096	0.000000	0.000000	0.010884
ESE	0.000527	0.002260	0.003219	0.000342	0.000000	0.000000	0.006349
SE	0.000547	0.001507	0.002945	0.000274	0.000000	0.000000	0.005273
SSE	0.000356	0.001918	0.002260	0.000205	0.000000	0.000000	0.004739
S	0.000551	0.002603	0.002945	0.000274	0.000000	0.000000	0.006373
SSW	0.000199	0.001781	0.001781	0.000137	0.000000	0.000000	0.003898
SW	0.000409	0.002671	0.003493	0.000479	0.000000	0.000000	0.007053
WSW	0.000395	0.002466	0.003562	0.000548	0.000000	0.000000	0.006970
W	0.000712	0.003836	0.007740	0.000959	0.000000	0.000000	0.013246
WNW	0.000473	0.002534	0.007055	0.001164	0.000000	0.000068	0.011295
NW	0.000653	0.004041	0.011301	0.001507	0.000000	0.000000	0.017502
NNW	0.000301	0.003219	0.007466	0.001027	0.000000	0.000000	0.012014
TOTAL	0.006918	0.037603	0.068151	0.008699	0.000000	0.000068	

RELATIVE FREQUENCY OF OCCURRENCE OF C STABILITY = 0.121438

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH C STABILITY = 0.002945

Fig. 3-5. Portion of Stability Wind Rose for Class C Stability

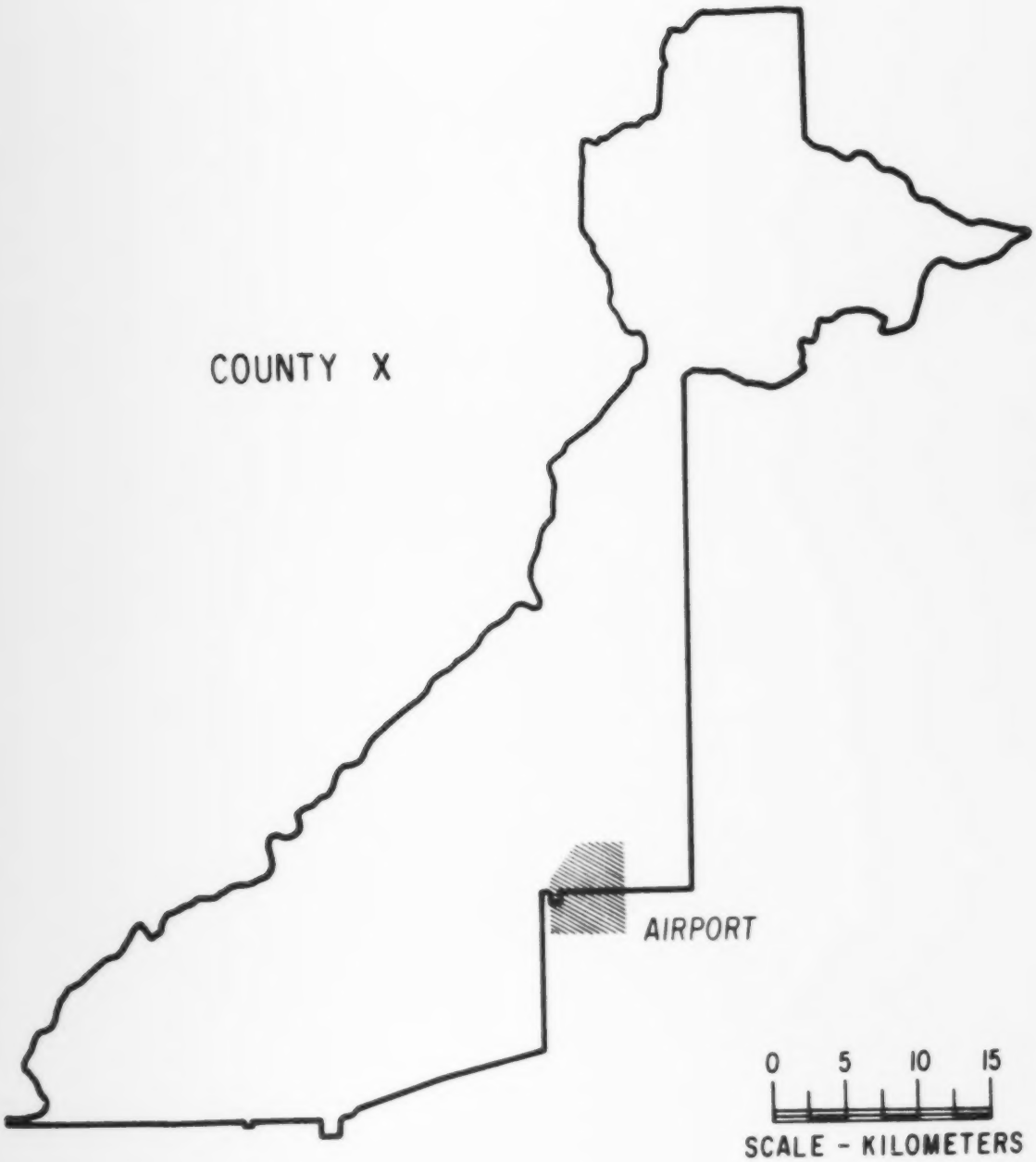

Fig. 3-6. Location of Airport Used for Meteorological Data

3.3.1 Definitions

Because of growth, development, and regulatory programs applied to pollutant-producing activities, the emission inventory can be expected to change with time. Three distinct inventory types can be identified for the purpose of the air quality analysis. They are:

Current inventory,
Updated inventory, and
Projected inventory.

The current inventory is that which exists on file with either the state air pollution control agency or with the federal EPA in the National Emissions Data System (NEDS). Most of this information was developed in the course of the original State Implementation Plan (SIP) development and represents data valid for the 1969-71 period. In many cases, states have updated portions of the inventory in the process of conducting enforcement activities or special studies.

The updated inventory, which will form the basis of the air quality analysis, represents information that is brought up to the most recent time period for which adequate data are available. In most cases this will probably be a 1973 or 1974 inventory. All portions of the inventory should be adjusted to the same year.

The projected inventory(ies) is a forecast of what emissions will amount to when growth, development, and regulatory programs have been accounted for. The projected inventory will be made for several years into the future starting with 1975. (In the unusual situation where there is adequate information available, the 1975 inventory can be developed as the updated inventory with succeeding years being projected inventories.)

This section will deal primarily with the development of an updated inventory using the current inventory as a starting point. The projected inventories will be discussed in the next section.

3.3.2 Data Required

The emission data is generally divided into the following six source categories:

Industrial process,
Fuel combustion,
Transportation,
Electricity generation,
Incineration, and
Miscellaneous.

Table 3-2 lists the subdivisions of each source category and the type of source included in each. Point sources are any stationary source emitting more than some designated minimum (usually 100 tons/year) of a pollutant. An area source is a collection of sources whose individual emission rates are small but whose collective impact may be large. A line source is a source that can be geometrically described best as a line (e.g., a highway). The line source description is used primarily in microscale analyses and need not be employed in all circumstances.

Table 3-3 lists the type of information desired for each source type. The list assumes that some form of modeling and strategy testing will be applied to the emission inventory and so includes parameters other than emission rates.

3.3.3 Sources of Information

Reference 7 lists numerous sources of information that can be used to develop an emission inventory. These fall into three basic categories:

Nationally available data - information published by sources that treat all areas of the country (e.g., Bureau of the Census; Departments of Interior, Commerce, Transportation, Treasury, and Army; National Coal Association, etc.).

Locally available data - information published for the region, state, or local area under study by local agencies (e.g., transportation, land use, air or water quality, energy studies, etc.).

EPA data - information published by EPA providing guidance on translating the above two activity data sets into estimates of emissions.

It must be emphasized that many forms of information are available and experience and judgment are the only guides as to which are the most useful.

Table 3-2. Emission Source Categories[a]

Source Category	Subdivisions	Source Description
Industrial Process	Chemical manufacture Food/agriculture Primary metals Secondary metals Mineral products Petroleum industry Wood products Evaporation Metal fabrication Leather products Textiles Inprocess fuel Other	Point
Fuel Combustion	Internal combustion External combustion	Point, Area
Transportation	Highway Vehicles Light duty gasoline autos Light duty gasoline trucks Motorcycles Heavy duty gasoline trucks Heavy duty diesel trucks Off-highway vehicles Rail locomotives Vessels Aircraft	Area, Line
Electricity Generation		Point
Incineration		Point, Area
Miscellaneous	Solvent evaporation Fires Fugitive dust	Point, Area, Line

[a]These categories are based on those described in References 7 and 13.

Table 3-3. Emission Source Data Required

Source Type	Data Desired
Point	Pollutant emission rates Process activity - type of process, process weight rate Control equipment - type and efficiency Stack parameters Geocoded location Compliance information Land area[a] Employment[a]
Area	Pollutant emission rates Area geometry Area geocoded location Area source type and activity level
Line	Pollutant emission rates Line geometry Line geocoded location Line source type and activity level

[a]May be useful for certain strategy considerations.

3.3.4 Special Considerations

There are several special considerations that will influence the development of the emission inventory.

Level of detail The level of detail in the inventory must be suitable to the analysis to be performed. It is not adequate to develop an inventory of a source category, for example, via crude approximation methods if the analysis will require a detailed consideration of that source's impact on air quality. Should the inventory be developed in an approximate way and the analysis show the need for more detail, it will be necessary to revise the data base. A judicious evaluation of the expected problem areas as outlined in Section 2 should avoid most of these false starts but even a careful preliminary review may not be able to foresee all the potential problems and some iteration may be necessary.

Reference 7 provides for several levels of effort in developing the inventory. The most detailed level (Level 3) should be used on major sources that are expected to impact significantly on regional air quality. The less

detailed procedures (Levels 1 and 2) can be used for minor sources. One method suggested for determining which are the major and minor sources is to start with the National Emissions Report[26] on emissions by Air Quality Control Region. The major sources can be identified as those that contribute greater than a threshold percentage (e.g., 5%) to the regional emission level. Sources that contribute less than the threshold level may be treated as minor sources. The threshold level chosen will vary with the resources available, the magnitude of the existing air quality problem and the degree of existing air pollution controls.

In general, it can be said that significant plan revisions based on the use of only Level 1 analyses throughout will not be acceptable without prior approval of the EPA Regional Office. This level of analysis will not give adequate accuracy for a substantial plan revision submission; an analysis comparable to Level 1 will be permitted only in special circumstances.

Subcounty spatial resolution Reference 13 describes methods of allocating emissions compiled on a countywide basis to subcounty areas for the purpose of improving the spatial resolution of the analysis. However, if data are available with a better-than-county resolution, Reference 13 presents techniques that project and allocate emissions directly to subcounty areas. The procedures outlined in Reference 7 and 13 may be used either in parallel or in series for all emission source categories. Familiarity with both references prior to starting the analysis is essential.

Actual v. allowable emissions In the development of the emission inventory it is important to keep in mind that the desired inventory is one that represents, as closely as possible, the actual situation. In this light, the effect of the following things must be considered:

Variances granted,
Non-compliance,
Compliance schedules, and
Improved performance.

The incorporation of stack test data into the inventory whenever possible will ensure that these considerations are included. For sources not yet in operation or for the projected inventories, the first approximation of

assuming that sources will just meet the emission regulations will be adequate; however, where information is available to the contrary, it should be included.

Applicability of strategies In developing the emission inventory, it is necessary to foresee what type of information might be needed to evaluate alternative control strategies. If, for example, it is felt that a strategy based on emission density (i.e., emissions per unit area) will receive consideration, then it is necessary to know what land area is currently owned by the sources in the inventory. If a strategy will be directed toward a certain type of process activity, it will be necessary to know which sources use that process. Although it will not be possible to foresee all potential problems, a careful preliminary review will eliminate most of the false starts.

3.3.5 Updating Procedures

The methods of generating an updated emission inventory as described in Reference 7 are schematically illustrated in Figs. 3-7 to 3-12. In general, the most detailed level of analysis relies on the use of an interview procedure to determine the necessary parameters directly from the major sources. The less detailed levels rely on estimates based on county or statewide data and/or national average values of several key items.

For industrial process emissions, the most reliable form of updating the inventory is to use the interview procedure. This is due primarily to the source-specific character of the emission sources. The Level 1 and 2 procedures illustrated by Fig. 3-7 will give only rough estimates of actual emissions.

For fuel combustion sources, the Level 1 and 2 procedures shown on Fig. 3-8 are somewhat more reliable than for process sources because of the availability of detailed fuel consumption data. However, as the next exercise will show, there is still a great deal of approximation that goes into these procedures.

For highway vehicles, the Level 1 procedures in Fig. 3-9 are very crude and should be used only in the event of complete lack of any other information. Data from transportation planning agencies is usually available to some degree to enable an analysis better than Level 1 to be performed.

INDUSTRIAL PROCESS EMISSIONS

(IPE)

LEVEL 1

[NEDS POINT SOURCE FILE EMISSIONS] → [AGGREGATE TO 13 NER CATEGORIES] X [EMPLOYMENT ADJUSTMENT FACTOR FROM COUNTY BUSINESS PATTERNS] = IPE

LEVEL 2

METHOD 1

USE LOCAL INVENTORY DATA.

METHOD 2

SAME AS LEVEL 1.

METHOD 3

SAME AS LEVEL 1, ONLY AGGREGATE TO SCC CLASSIFICATION AND USE SCC EMPLOYMENT.

LEVEL 3

METHOD 1

INTERVIEW TOP 95% OF EMITTERS FROM NEDS FILE.

METHOD 2

INTERVIEW TOP 90% OF EMITTERS FROM NEDS FILE.

METHOD 3

INTERVIEW TOP 90% OF EMITTERS OF MAJOR POLLUTANT FROM NEDS FILE.

Fig. 3-7. Update Procedures for Industrial Process Sources

FUEL COMBUSTION EMISSIONS

(FCE)

LEVEL 1,2

[ESTIMATE FUEL CONSUMPTION FROM STATEWIDE DATA] → [PRORATE STATE FUEL USE TO COUNTY] X [EMISSION FACTORS] = FCE

LEVEL 3

[INTERVIEW DEALERS AND MAJOR USERS TO DETERMINE FUEL CONSUMPTION] X [EMISSION FACTORS] = FCE

Fig. 3-8. Update Procedures for Fuel Combustion Sources

TRANSPORTATION EMISSIONS

HIGHWAY VEHICLE EMISSIONS

(HVE)

LEVEL 1

[DETERMINE COUNTY GAS AND DIESEL OIL SALES FROM TAX DATA] → [ESTIMATE VMT BY (GAS SOLD) X (VEHICLE TYPE DISTRIBUTION) X (AVERAGE MPG)] X [VEHICLE EMISSION FACTORS] = HVE

LEVEL 2

[DETERMINE VMT FROM LOCAL STUDIES] → [DISAGGREGATE BY VEHICLE TYPE IF NECESSARY] X [VEHICLE EMISSION FACTORS] = HVE

LEVEL 3

[DETERMINE VMT, SPEED, VEHICLE CLASS AND AGE DISTRIBUTION FROM LOCAL STUDIES] X [VEHICLE EMISSION FACTORS] = HVE

Fig. 3-9. Update Procedures for Highway Vehicles

ELECTRIC GENERATION EMISSIONS
(EGE)

LEVEL 1,2

[DETERMINE FUEL USE, % SULFUR, % ASH FROM LOCAL OR NATIONAL SOURCES] X [EMISSION FACTORS] = EGE

LEVEL 3

[DETERMINE FUEL USE, % SULFUR, % ASH FROM LOCAL OR NATIONAL SOURCES] → [USE STACK TEST DATA AND/OR EMISSION FACTORS] = EGE

Fig. 3-10. Update Procedures for Electric Generation Sources

INCINERATION EMISSIONS

(IE)

LEVEL 1

[ESTIMATE QUANTITY OF WASTE INCINERATED USING NATIONAL AVERAGES] → [DISAGGREGATE TO POINT AND AREA SOURCE USING EXISTING DISTRIBUTION] X [EMISSION FACTORS] = IE

LEVEL 2,3

[DETERMINE QUANTITY OF WASTE INCINERATED FROM LOCAL STUDIES] X [EMISSION FACTORS] = IE

Fig. 3-11. Update Procedures for Incineration Sources

MISCELLANEOUS SOURCE EMISSIONS

GASOLINE HANDLING EVAPORATION EMISSIONS

(GHE)

SOLVENT USE EVAPORATION EMISSIONS

(SUE)

LEVEL 1,2

GASOLINE HANDLING	[DETERMINE GAS SALES FROM TAX DATA]	X	[EMISSION FACTORS]	=	GHE
SOLVENT USE	[ESTIMATE SOLVENT USE FROM NATIONAL PER CAPITA AVERAGES]	X	[EMISSION FACTORS]	=	SUE

LEVEL 3

[INTERVIEW GASOLINE AND SOLVENT DEALERS TO DETERMINE USE]	X	[EMISSION FACTORS]	=	GHE, SUE

OTHER SOURCE CATEGORIES HANDLED AS NEEDED

Fig. 3-12. Update Procedures for Miscellaneous Sources

For electric generation, there are adequate sources of information for virtually the entire country such that even a Level 1 analysis as shown on Fig. 3-10 should be fairly accurate. This is probably the source category that can be analyzed in the most detailed fashion with the smallest effort needed for information gathering.

For incineration, the Level 1 analysis shown on Fig. 3-11 is crude since national averages are used. The use of local studies is significantly more accurate.

For the gasoline handling and solvent use, miscellaneous sources on Fig. 3-12, the Level 1 and 2 analyses are crude because of the use of national average consumption figures, but the Level 3 analysis would require a fairly extensive effort due to the large number of small sources.

3.3.6 Illustration of County X

Table 3.4 summarizes the baseline year emissions for County X tabulated in the National Emissions Report format specified in Reference 7. The total particulate emissions are 29,524 tons/year. The biggest contributors are industrial process sources (37%), especially the secondary metals and mineral products industries, industrial fuel combustion (11%), industrial and commercial/institutional incineration (27%), and fugitive dust from agriculture, unpaved roads, and construction (20%).

Table 3-4. County X Baseline Emissions, 1973

COUNTY X

YEAR 1973 Baseline

County Base Year Emissions Report

SOURCE				EMISSIONS TONS PER YEAR				
				PART	SOX	NOX	HC	CO
FUEL COMBUSTION EXTERNAL	RESIDENTIAL FUEL (AREA)	ANTHRACITE COAL						
		BITUMINOUS COAL		18				
		DISTILLATE OIL		18				
		RESIDUAL OIL						
		NATURAL GAS		193				
		WOOD						
		TOTAL		229				
	ELECTRIC GENERATION (POINT)	ANTHRACITE COAL						
		BITUMINOUS COAL						
		LIGNITE						
		RESIDUAL OIL						
		DISTILLATE OIL						
		NATURAL GAS						
		PROCESS GAS						
		COKE						
		SOLID WASTE COAL						
		TOTAL						
	INDUSTRIAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	67				
			POINT	2705				
		LIGNITE	POINT					
		RESIDUAL OIL	AREA	2				
			POINT	570				
		DISTILLATE OIL	AREA	10.6				
			POINT	1				
		NATURAL GAS	AREA	153				
			POINT	7				
		PROCESS GAS	AREA					
			POINT					
		COKE	POINT					
		WOOD	AREA					
			POINT					
		LIQUEFIED PETROL GAS	POINT					
		BAGASSE	POINT					
		OTHER	POINT					
		TOTAL	AREA	329				
			POINT	3283				

Table 3-4. County X Baseline Emissions, 1973 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
FUEL COMBUSTION EXTERNAL (CONTINUED)	COMMERCIAL INSTITUTIONAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	61				
			POINT					
		LIGNITE	POINT					
		RESIDUAL OIL	AREA					
			POINT					
		DISTILLATE OIL	AREA	29				
			POINT					
		NATURAL GAS	AREA	138				
			POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		OTHER	POINT					
		TOTAL	AREA	228				
			POINT					
	OTHER		POINT					
	TOTAL EXTERNAL COMBUSTION		AREA	785				
			POINT	3283				
FUEL COMBUSTION INTERNAL	ELECTRIC GENERATION	DISTILLATE OIL						
		NATURAL GAS						
		DIESEL						
		OTHER						
		TOTAL						
	INDUSTRIAL FUEL	DISTILLATE OIL						
		NATURAL GAS						
		GASOLINE						
		DIESEL						
		OTHER						
		TOTAL						
	COMMERCIAL INSTITUTIONAL FUEL	DIESEL						
		TOTAL						
	ENGINE TESTING	AIRCRAFT						
	TOTAL INTERNAL COMBUSTION							
TOTAL FUEL COMBUSTION		AREA		785				
		POINT		3283				

Table 3-4. County X Baseline Emissions, 1973 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
INDUSTRIAL PROCESS (POINT)	CHEMICAL MANUFACTURING			1				
	FOOD AGRICULTURE			5				
	PRIMARY METAL			6274				
	SECONDARY METALS			41				
	MINERAL PRODUCTS			4476				
	PETROLEUM INDUSTRY							
	WOOD PRODUCTS							
	PROCESS EVAPORATION							
	METAL FABRICATION							
	LEATHER PRODUCTS							
	TEXTILE MANUFACTURING							
	INPROCESS FUEL							
	OTHER NOT CLASSIFIED							
	TOTAL			10797				
SOLID WASTE DISPOSAL	GOVERNMENT (POINT)	MUNIC INCIN						
		OPEN BURNING						
		OTHER		8				
		TOTAL		8				
	RESIDENTIAL (AREA)	ON SITE INCIN						
		OPEN BURNING						
		TOTAL						
	COMMERCIAL INSTITUTIONAL	ON SITE INCIN ERATION	AREA	917				
			POINT					
		OPEN BURNING	AREA	1703				
			POINT					
		APARTMENT	POINT					
		OTHER	AREA					
			POINT					
		TOTAL	AREA	2620				
			POINT					
	INDUSTRIAL	ON SITE INCIN ERATION	AREA	170				
			POINT	436				
		OPEN BURNING	AREA	4688				
			POINT					
		AUTO BODY INCIN	POINT					
		OTHER	POINT					
		TOTAL	AREA	4858				
			POINT	436				
	TOTAL SOLID WASTE DISPOSAL		AREA	7479				
			POINT	444				

Table 3-4. County X Baseline Emissions, 1973 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
TRANSPORTATION (AREA)	LAND VEHICLES	GASOLINE	LIGHT DUTY	713				
			HEAVY DUTY	108				
			OFF HIGHWAY					
			TOTAL					
		DIESEL	HEAVY DUTY					
			OFF HIGHWAY					
			RAIL					
			TOTAL					
	AIRCRAFT	MILITARY						
		CIVIL						
		COMMERCIAL						
		TOTAL						
	VESSELS	BITUMINOUS COAL						
		DIESEL FUEL						
		RESIDUAL OIL						
		GASOLINE						
		TOTAL						
	GAS HANDLING EVAPORATION LOSS							
	TOTAL TRANSPORTATION			821				

Table 3-4. County X Baseline Emissions, 1973 (Continued)

SOURCE			PART	SOX	NOX	HC	CO
MISCELLANEOUS (AREA)	SOLVENT EVAPORATION	INDUSTRIAL SOURCES (AREA)					
		DRY CLEANING					
	FIRES	STRUCTURAL					
		FROST CONTROL					
		SLASH BURNING					
		WILD FOREST					
		AGRICULTURAL					
	DUST CAUSED BY HUMAN AGITATION OF THE AIR	UNPAVED ROADS	1439				
		UNPAVED AIRSTRIPS					
		PAVED ROADS					
		MINERAL PROCESSING					
		TILLING ACTIVITIES	877				
		LOADING CRUSHED ROCK SAND GRAVEL					
		CONSTRUCTION	3600				
	AIRBORNE DUST CAUSED BY NATURAL WINDS	STORAGE PILES					
		TILLED LAND					
		UNTILLED LAND					
		Total Miscellaneous	5916				
GRAND TOTAL		AREA	15000				
		POINT	14524				

PROBLEM 3-2

Update the County X emission inventory for fuel combustion sources using a Level 2 analysis; that is, use statewide fuel consumption data and determine the county's share. Follow the procedures in Reference 7 using the copies of Tables 2.1, 2.3, 2.4, and 2.5 from that report, which are attached here as Figs. 3-13 to 3-16. All of the necessary data are in the appendixes.

Table 2.1
Baseline County Fuel Use
(External Combustion Unless Noted Otherwise)

SOURCE		MAJOR FUELS								MINOR FUELS										ELECTRICITY
		COAL																		
		ANTHRACITE	BITUMINOUS	LIGNITE	RESIDUAL	DISTILLATE	DISTILLATE INTERNAL	NATURAL GAS	NATURAL GAS INTERNAL	PROCESS GAS	LPG	OKP	WOOD	OHGASSE	DIESEL INTERNAL	GASOLINE INTERNAL	ENGINE TESTING INTERNAL	OTHER	OTHER INTERNAL	RESIDUAL FUEL SUBSTITUTE
INDUSTRIAL	POINT																			
	AREA																			
COMMERCIAL INSTITUTIONAL	POINT																			
	AREA																			
RESIDENTIAL	AREA																			
UNITS		TONS			1000 GALLONS			10^{6} CU FT			1000 GAL	TONS			1000 GALLONS					KWH

[illegible]

[illegible]

Fig. 3-13. Baseline County Fuel Use, Table 2.1 from Ref. 7

Table 2.3
Sulfur and Ash Content of Coal and Heating Oil

SOURCE	PERCENT SULFUR*					PERCENT ASH*		
	ANTHRACITE COAL	BITUMINOUS COAL	LIGNITE COAL	RESIDUAL OIL	DISTILLATE OIL	ANTHRACITE COAL	BITUMINOUS COAL	LIGNITE COAL
INDUSTRIAL								
COMMERCIAL INSTITUTIONAL								
RESIDENTIAL								
ELECTRICITY GENERATION								

DATA SOURCES _____

BASE YEAR _____

*SULFUR AND ASH CONTENT ARE GIVEN PER UNIT WEIGHT FOR COAL, PER UNIT VOLUME FOR OIL

Fig. 3-14. Sulfur and Ash Content of Coal and Heating Oil, Table 2.3 from Ref. 7

Table 2.4
Apportionment of State Heating Oil Sales Totals to Customer Categories

LINE	SALES COMPONENT	FUEL USE, 1000 GAL	
		RESIDUAL	DISTILLATE
1	TOTAL HEATING OIL SALES		
2	COMM INST EMPLOYMENT FACTOR		
3	INDUSTRIAL EMPLOYMENT FACTOR		
4	COMM INST OIL FRACTION		
5	INDUSTRIAL OIL FRACTION		
6	SALES TO MILITARY		
7	SALES TO INDUSTRY		
8	OIL COMPANY USE		
9	RESIDENTIAL USE		
10	TOTAL COMM INST USE		
11	TOTAL INDUSTRIAL USE		

CALCULATION LEVEL _____

Fig. 3-15. Apportionment of State Heating Oil Sales Totals to Consumer Categories, Table 2.4 from Ref. 7

Table 2.5
Baseline State Fuel Use
(External Combustion Unless Noted Otherwise)

SOURCE		[illegible]																			
		[illegible]																			
		[illegible]																			
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
INDUSTRIAL	POINT																				
	AREA																				
COMMERCIAL INSTITUTIONAL	POINT																				
	AREA																				
RESIDENTIAL	AREA																				
UNITS			TONS			1000 GALLONS			10^6 CUFT			1000 GAL		TONS			1000 GALLONS				KWH

CALCULATION LEVEL _____
DATA SOURCES _____

*ALL INTERNAL COMBUSTION REFERS TO STATIONARY SOURCES ONLY

Fig. 3-16. Baseline State Fuel Use, Table 2.5 from Ref. 7

PROBLEM 3-3

Estimate the emissions from fugitive dust sources in County X. The necessary equations can be found in Appendix F. Assume the following information is known:

Agricultural tilling: 194,000 acres are under cultivation; the land is tilled, on the average, once a year; the silt content (i.e., portion of particles in the surface soil of size between 2 μ and 50 μ in diameter as determined by the Buoyocous hydrometer) is 45%.

Unpaved roads: 30 miles of unpaved roads with an average traffic load of 60 veh/day, the average speed is 35 miles per hour, the road silt content is 12%.

Heavy construction: 250 acres are under construction, the activity continues year-round.

4. ESTIMATING FUTURE EMISSIONS

Accumulated experience in the preparation and evaluation of air quality attainment and maintenance plans has emphasized the need for considering the effect of growth and development on pollutant emission levels. This was recognized in the early State Implementation Plan (SIP) efforts but has only lately become a significant aspect of all SIP revision actions. This section is aimed at describing the methodologies for projecting future trends in emission levels.

4.1 PROJECTION REQUIREMENTS

The initial regulations for the development of air quality maintenance plans[14] indicated that the time period to be covered was the 10-year span between 1975 and 1985. Proposed revisions to these regulations recognize that the uniform 10-year period:

> Does not reflect coordination with other on-going federal planning programs and
>
> Does not recognize the unique problems of each study area.

To address these situations, the revisions include the requirements indicated on Fig. 4-1.

Where another federally-sponsored planning program is underway (e.g., Department of Transportation 3-C plan, Department of Housing and Urban Development's 701 comprehensive plan, or EPA's area-wide wastewater treatment plan under Section 208 of the Water Pollution Control Act Amendments of 1972) then the air quality analysis must address the time period extending furthest into the future of these programs. Where there is no additional federally-funded planning program, then the analysis must address, at a minimum, the 10-year period to 1985. These same timing considerations must be reflected in any submitted air quality maintenance plan.

To allow for flexibility in addressing the problems of each study area, the EPA Regional Administrators are given the authority to allow for a less detailed analysis for the period beyond 1985. Similarly, discretion is given to the Regional Administrator to accept air quality maintenance or long-range air quality management plans covering less than the 10-year period but not less than 3 years.

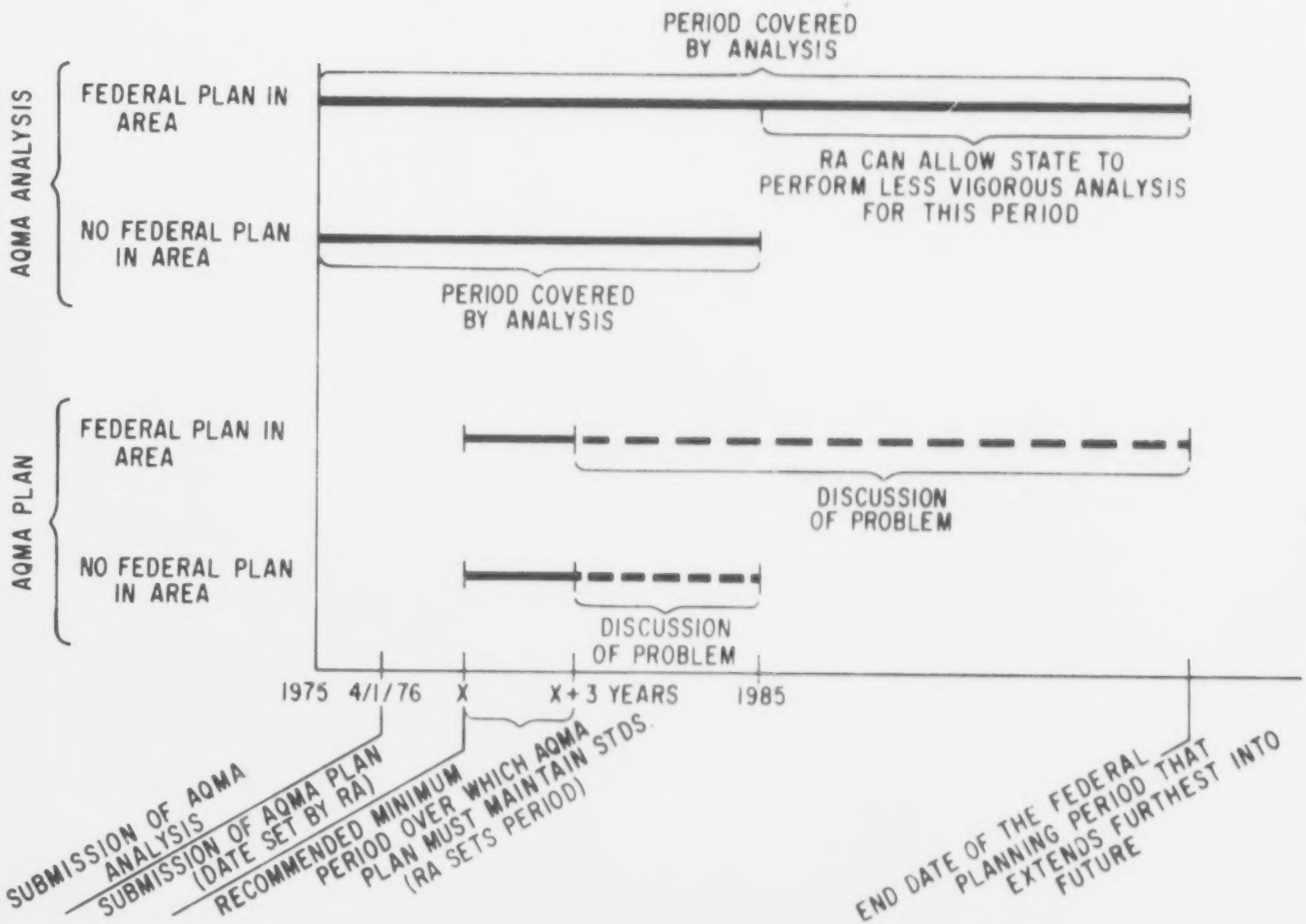

Fig. 4-1. Air Quality Analysis Time Period Requirements

4.2 PROJECTED VARIABLES

The projection of future emissions brings the air quality analysis to the least rigorous portion of the analysis procedures. Forecasting the future has never been amenable to a truly scientific approach and relies, in the case of the air quality analysis, on a combination of considered judgment and best guesses. Using the six emission categories, the variables that must be projected are the following:

Industrial process activity,
Fuel consumption,
Transportation activity,
Electricity demand,
Solid waste generation, and
Miscellaneous emission-producing activity.

These may be converted to emissions using emission factors.[27] In addition, the temporal and spatial distribution of these variables (e.g., when new plants will come on line and where they will be located) is important to the air quality analysis. In most situations, projections of these parameters are not available or are available only on a cruder scale than needed for an adequate air quality analysis, especially in attainment/maintenance problem areas. Reliance must then be placed on surrogate variables such as population, employment, land use, earnings, and others that are projected with reasonable accuracy and precision and that can then be transformed into growth factors for the desired variables. Figure 4-2 illustrates this process. The surrogate variables are those most frequently used by planning groups in developing comprehensive regional plans.

Projections of population, and to some extent employment, have customarily been the starting point for the projection of other variables. Overall size is the most important factor in population projection, but other characteristics of the population composition can be important for determining activity levels. The age distribution of the population, distribution of household sizes, and the income composition of the population affect the details of the need for residential areas and community facilities. Likewise, more than just the total employment figures are of value in projecting the future industrial and commercial/institutional growth of the region.

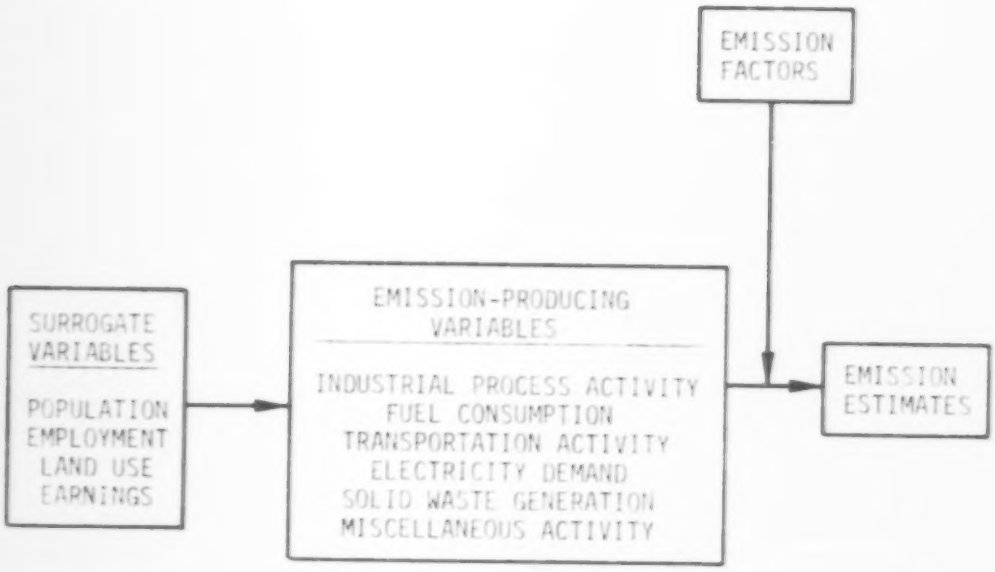

Fig. 4-2. Use of Surrogate Variables

Separation into basic and non-basic employment, for example, leads to some indication of the probable land requirements for industrial and commercial/institutional areas. Further disaggregation of the projected employment on the basis of Standard Industrial Classification (SIC) categories or EPA's Source Classification Code (SCC) System will be useful in a refinement of these requirements.

Changes in population are accompanied by changes in the area occupied by various land uses (e.g., residential, commercial/institutional, industrial, transportation, vacant, etc.). New plant locations and industrial process activity (measured, for example, by earnings estimates) are private decisions that integrate site-specific characteristics (physical features, local regulations, access) with regional and, in some cases, extraregional considerations (demand patterns, regional and interregional transportation, location of inputs).

There are numerous techniques available to regional planners to make estimates of the surrogate variables. Reference 4 outlines some of the more widely used procedures. Appendix D contains some of the background material and a computer printout of the projected population and land use for County X based on the regional planning commission's efforts. It is emphasized that, while the data are based on the Atlanta Regional Commission's work, some information has been changed to suit the needs of this example. Thus, the data should not be viewed as corresponding to actual projections for the Atlanta area and is included here for illustrative purposes only.

4.3 ACTIVITY SCENARIOS

Estimates of future activity are dependent on the assumptions made concerning levels of growth and growth management policies. Every regional planning group uses its own methodologies and assumptions in arriving at these estimates. A set of assumptions leads to one possible picture, or scenario, of the future. Because it is not possible to fully predict the detailed decisions that will determine the future nor to foresee the events and discoveries that influence the decisions, a number of futures can be hypothesized. Several scenarios of the future might be available for air quality management planning that indicate both the more likely future activity levels and the range of levels that is readily conceivable.

An elusive, but valuable, concept is that of the most probable growth scenario. Most probable growth customarily is taken as projections of current trends, altered by known constraints and incorporating already apparent changes in growth-affecting policies and actions. As such, it is a basic reference scenario for evaluating the desirability of intervention and the effectiveness of proposed alternatives. Planning agencies often develop such a scenario for just this purpose.

Often the reason for variations in projected development scenarios is the mandated orientation of the agencies preparing the estimates. Transportation planning groups base their projections on various transportation scenarios (e.g., highway development emphasis, transit emphasis, etc.). Comprehensive planning groups may use land-use development scenarios as the driving mechanism. These differences can result in wide discrepancies in the projection of regional development. One of the problems that the lead agency in the air quality analysis has is the reconciliation of the various planning outputs. In order to use information from the various groups, it will be necessary to insure that they are based on compatible assumptions and data bases. The need for a coordinated effort on the part of the involved organizations is reemphasized by this need for a unified projection plan upon which to base the analysis. The question of how many alternative scenarios should be evaluated as part of the air quality analysis is answered by the available resources. Certainly the "most probable growth" situation should be given detailed review. In the interest of determining the compatibility of other alternatives with air quality constraints, it may be useful to consider additional possibilities although this would not be required for the analysis. If, however, there is strong feeling that other scenarios have a reasonable chance of being implemented and would impact on the region's air quality, then analysis of their air quality conditions at this stage may save the necessity of developing a major revision to the air quality management plan at a later date.

4.4 SOURCES OF DATA

Long-range planning has been carried out for many years in a number of areas. The information required for the air quality analysis should build on the experience and background of the planning groups that have been involved

in these activities. There are four federally-funded planning programs that should be able to provide some framework for the projections. They are:

HUD 701 planning,
HEW 3-C planning,
EPA 208 planning,
CZM planning, and
OBERS growth projections.

There are, of course, numerous local and regional studies that can be used to supplement this information.

4.4.1 HUD 701 Planning

The planning assistance program defined by Section 701 of the Housing Act of 1954 and subsequent revisions is the Department of Housing and Urban Development's (HUD) main program of support for comprehensive planning. It has been in existence for a number of years and presently provides funds to all the states, 70% of the cities of over 50,000 population, more than 80% of the metro and non-metro area-wide planning organizations, and approximately 1,200 counties and smaller municipalities. Because the priorities are set by such a broad scope of recipients, a variety of approaches is permitted to the general requirement that 701-supported activities address the major growth or no growth decisions facing the jurisdiction; the diversity is represented by such subjects as controls over strip mining, preservation of prime agricultural land, government cost cutting, energy saving programs, and review of the status of local land controls and land use planning.

The Housing and Community Development Act of 1974 contains new requirements for 701 recipients. The requirement that the planning effort be comprehensive has been specified to mean, at a minimum, the inclusion of a housing element and a land use element that reflects consideration of the principal land use issues facing the jurisdiction. Many of the previous 701-supported planning programs did not include a land use element, but satisfactory progress toward developing a land use plan must be demonstrated for assistance to be continued after August 1977. It is also necessary that each jurisdiction should work toward the establishment of a unified or integrated system for land use planning and policy making, which includes the principal

land use related planning and regulatory process. As part of this coordination requirement, the 701 activities must include a consideration of the current status of other planning that impacts land use (e.g., coastal zone, air and water quality, transportation, and solid-waste planning), related implementation activities, and the relationship between the 701 work program and such other planning or implementation efforts.

Three additional requirements are a part of the current 701 program: (1) The planning must attempt to deal with the complexities of the intergovernmental structure; (2) citizens must be involved at significant points in the process; and (3) the planning should serve the needs of growth management as well as protection of critical environmental features.

4.4.2 FHWA 3-C Planning

The Federal Highway Administration has been administering the requirements of the Federal Highway Act of 1962, which states that all federally-assisted highway projects be a part of Continuing, Comprehensive transportation planning process carried on Cooperatively in the state and local communities. The 3-C process has been carried out with varying levels of sophistication throughout the country. The basic procedure is divided into four phases. The data collection phase assembles information on current land use, population, dwelling units, employment, traffic volume and patterns, and existing transportation facilities. In the analysis phase, analytical methods such as comprehensive land use models and trip generation, distribution and modal split models are used to develop the pattern of travel demand and form the basis for developing travel projections. In the projection phase, land use and travel demand are forecast for a variety of alternatives. The continuing planning and implementation phase results in the development of the area's long-range transportation program. Reference 4 gives a more detailed description of the 3-C process.

4.4.3 EPA 208 Planning

EPA is administering the requirements of Section 208 of the Federal Water Pollution Control Act, which deals with areawide wastewater treatment management. In regions that require management plans for the attainment of water quality standards, areawide agencies have been designated to carry out

the planning effort. Other agencies may have the responsibilities for implementation of the plans. In many ways similar to the air quality analysis process, the 208 planning process seeks to identify water quality problems associated with construction and growth over a 20-year period and to suggest appropriate technical and regulatory alternatives as well as growth and development options, to assure continuing achievement of satisfactory water quality. Most 208 plans will be due about mid-1977. It is entirely possible that a single regional planning agency could and should be responsible for developing projection indices for both air quality and water quality planning. A critical parameter in attempting to coordinate the goals of these two, or any other planning programs, is the time scale frame by which results are required.

4.4.4 CZM Planning

The Coastal Zone Management Act of 1972 establishes a national policy for the development of a program to manage the land and water resources of the coastal zone. The act recognizes the multiplicity of uses and values ascribed to lands and waters within the coastal zone and encourages the management of these lands through an approved plan that incorporates important ecological, cultural, esthetic, and economic values. States are encouraged to rely upon and coordinate their activities with appropriate local governments and regional agencies in the development of a coastal zone management plan (CZMP). Incentives to prepare and administer a comprehensive CZMP are provided, but no specific land or water use decisions are made. States submitting grant requests for programs that impinge on the CZMP must show that these programs are consistent with the approved plan. Further, according to Section 307(f) of the act, requirements of the Clean Air Act as amended and subsequent federal regulations will be incorporated into the CZMP. An important point of the act is that the state land use control authority, when necessary, can supersede local governmental authority. This is in marked contrast to the tradition under which all 50 states have delegated land use regulation power to local city or county governments.

4.4.5 OBERS Growth Projections

The projections of growth based on the work of the Office of Business Economics (OBE), presently the Bureau of Economic Analysis of the Department

of Commerce, and the Economic Research Services (ERS) of the Department of Agriculture form a last resort to be used in areas where no other planning information is available. The projections are available by state, water resource area, OBE economic area, Air Quality Control Region, and Standard Metropolitan Statistical Area and include population, employment, and earnings (disaggregated by 27 industrial categories that are basically 2-digit SIC classes). The projections are derived by an apportioning of national data to the smaller subareas and are, as such, only crude estimates. Appendix D contains a tabulation of the OBERS projections for the Atlanta Metropolitan AQCR that contains County X.

4.5 PROJECTION METHODOLOGIES

The methodology used to forecast emission levels is conceptually simple, although, in practice, one encounters some difficulty in identifying the appropriate parameters to insert into the equations. Emissions are generally estimated by the following equation:

$$\text{Emissions} = \begin{matrix}\text{Process}\\ \text{Activity}\end{matrix} \times \begin{matrix}\text{Emission}\\ \text{Factor}\end{matrix} \times \left(1 - \begin{matrix}\text{Control}\\ \text{Efficiency}\end{matrix}\right) \qquad (4\text{-}1)$$

The process activity is measured in units such as fuel consumption, raw material input or quantity of finished product. The emission factor is an emission rate per unit of process activity and usually represents uncontrolled emissions. The control efficiency accounts for the use of some form of control device to reduce emissions and is a percentage removal of pollutant.

When projecting emissions, the established procedure is to forecast the change in process activity that will result from economic growth and development. The implementation of air pollution control regulations may affect the activity (e.g., in a transportation control plan) but will most often affect the emission factor and/or the control efficiency applicable to specific sources. Because many regulatory programs differentiate between existing, modified, or new sources in the application of control regulations, it is necessary to maintain this distinction in an air quality analysis. Thus, projected emissions must be disaggregated into three components:

$$\begin{matrix}\text{Projected}\\ \text{Emissions}\end{matrix} = \begin{matrix}\text{Emissions}\\ \text{from existing}\\ \text{sources}\end{matrix} + \begin{matrix}\text{Emissions from}\\ \text{modifications to}\\ \text{existing sources}\end{matrix} + \begin{matrix}\text{Emissions}\\ \text{from new}\\ \text{sources}\end{matrix} \qquad (4\text{-}2)$$

The emissions from each of these types of sources is computed in the standard way (i.e., as the product of a process activity, emission factor, and control efficiency factor), but with different values for these parameters. Unfortunately, it is not always straightforward to identify the distribution among them. For example, planning data generally indicates overall growth for a given industry (e.g., steel) but does not identify how much of the growth will be at existing sources and how much will be at new sources.

To accurately estimate emissions, the process activity must be disaggregated into its three components:

$$\text{Projected Activity} = \begin{matrix}\text{Activity due}\\ \text{to existing}\\ \text{sources}\end{matrix} + \begin{matrix}\text{Activity due}\\ \text{to modifications}\\ \text{of existing sources}\end{matrix} + \begin{matrix}\text{Activity due}\\ \text{to new}\\ \text{sources}\end{matrix} \qquad (4\text{-}3)$$

In the application of air pollution control regulations, the last two components are generally subject to more stringent emission controls (either more stringent state regulations or federal New Source Performance Standards). Also, the first two components can be used to identify the spatial distribution of emissions, while the last component represents an unknown in terms of source location. A further complication to the calculation of projected emissions is the fact that the activity at existing sources is variable and dependent upon two important factors: the maximum capacity available at existing facilities (e.g., if a plant is operating at 90% capacity it can only absorb a 10% increase without modification), and the rate of retirement of existing facilities (e.g., the activity at existing facilities is not, in general, constant over the entire projection period because of the closing down of obsolete equipment).

In the ideal situation, the agency performing an air quality analysis would have information available on projected activity disaggregated into its three components, disaggregated by industry type, and disaggregated spatially. In reality, only a portion of this information will be available and estimates of the disaggregation will have to be made. This section will focus on estimating the component and industry distinctions, while the next will concentrate on the spatial distributions.

Figures 4-3 to 4-8 schematically illustrate the emission projection procedures outlined in Reference 7. For industrial process emissions, as

PROJECTED INDUSTRIAL PROCESS EMISSIONS
(PIPE)

LEVEL 1

METHOD 1

[BASELINE EMISSIONS] X [OBERS GROWTH FACTORS FOR 13 NER PROCESS CATEGORIES] X [CONTROL EFFICIENCIES FOR 13 NER PROCESS CATEGORIES] = PIPE

METHOD 2

SAME AS METHOD 1, ONLY USE SCC CATEGORIES.

LEVEL 2

SAME AS LEVEL 1, METHOD 2, ONLY USE LOCALLY AVAILABLE GROWTH PROJECTIONS.

LEVEL 3

INTERVIEW INDUSTRIES TO DETERMINE GROWTH AND EXPANSION PLANS.

Fig. 4-3. Emission Projection Procedures for Industrial Process Sources

PROJECTED FUEL COMBUSTION EMISSIONS

(PFCE)

LEVEL 1

[CONVERT BASELINE COUNTY FUEL USE TO BTU EQUIVALENTS] X [SCALE RESIDENTIAL BTU GROWTH BY POPULATION GROWTH, ALL OTHERS BY OBERS] X [DISTRIBUTE BTU GROWTH BY FUTURE FUEL MIX] X [EMISSION FACTORS INCLUDING CONTROLS] = PFCE

LEVEL 2

SAME AS LEVEL 1, ONLY USE LOCALLY AVAILABLE GROWTH PROJECTIONS FOR EACH CATEGORY.

LEVEL 3

SAME AS LEVEL 1, ONLY USE LOCALLY AVAILABLE GROWTH PROJECTIONS FOR EACH CATEGORY AND INTERVIEW RESULTS FOR FUEL MIX AND OTHER DISTRIBUTION CHANGES.

Fig. 4-4. Emission Projection Procedures for Fuel Combustion Sources

PROJECTED TRANSPORTATION EMISSIONS

PROJECTED HIGHWAY VEHICLE EMISSIONS

(PHVE)

LEVEL 1

[BASELINE VMT] X [POPULATION GROWTH FACTOR] X [VEHICLE EMISSION FACTORS] = PHVE

LEVEL 2,3

[DETERMINE PROJECTED VMT FROM LOCAL STUDIES] X [VEHICLE EMISSION FACTORS] = PHVE

Fig. 4-5. Emission Projection Procedures for Highway Vehicles

PROJECTED ELECTRIC GENERATION EMISSIONS

(PEGE)

LEVEL 1

[DETERMINE PROJECTED QUANTITY OF ELECTRICITY TO BE GENERATED] → [DETERMINE FUEL USE DISTRIBUTION AND FUEL REQUIRED PER KWH] → [COMPUTE FUEL USE] X [EMISSION FACTORS] = PEGE

LEVEL 2

[DETERMINE PROJECTED FUEL USE FROM PUBLISHED DATA] X [EMISSION FACTORS] = PEGE

LEVEL 3

SAME AS LEVEL 2, USING INTERVIEW RESULTS.

Fig. 4-6. Emission Projection Procedures for Electric Generation Sources

PROJECTED INCINERATION EMISSIONS
(PIE)

LEVEL 1

[BASELINE SOLID WASTE GENERATED] X [OBERS GROWTH FACTORS FOR MFG, COMM/INST, RESID] → [APPORTION BY DISPOSAL METHOD] X [EMISSION FACTORS] = PIE

LEVEL 2

SAME AS LEVEL 1, ONLY USE LOCALLY AVAILABLE GROWTH FACTORS.

LEVEL 3

USE INTERVIEW RESULTS TO DETERMINE WASTE GENERATED AND DISPOSAL METHODS.

Fig. 4-7. Emission Projection Procedures for Incineration Sources

PROJECTED MISCELLANEOUS SOURCES EMISSIONS

GASOLINE HANDLING EMISSIONS

(PGHE)

SOLVENT USE EVAPORATION EMISSIONS

(PSUE)

LEVEL 1,2,3

GASOLINE HANDLING	[SCALE GASOLINE USE BY VMT PROJECTION OR INTERVIEW]	X	[EMISSION FACTORS]	=	PGHE
SOLVENT USE	[SCALE SOLVENT USE BY POPULATION GROWTH]	X	[EMISSION FACTORS]	=	PSUE

OTHER SOURCE CATEGORIES HANDLED AS NEEDED

Fig. 4-8. Emission Projection Procedures for Miscellaneous Sources

shown in Fig. 4-3, the Level 1 and 2 analyses rely on the application of a growth factor for an industry. This will, in general, mean that no information will be available to directly identify new, modified, and existing source contributions and some estimates must be made. Only the Level 3 analysis can supply this information, and even there, it may not do so in all cases. For fuel combustion sources, as shown on Fig. 4-4, the same comments apply as for process sources; i.e., only Level 3 will give a direct indication of the source contributions.

For highway vehicles, shown on Fig. 4-5, the "activity" of new sources is represented by the vehicle age distribution that is available from local registration data. For electric generation, as shown on Fig. 4-6, there is a significant amount of information available on power plant expansion plans to enable a good estimate of future activity to be made. A Level 2 or 3 analysis should be relatively easy to effect.

For incineration, on Fig. 4-7, the Level 1 and 2 analyses provide no information on new, modified, and existing source contributions. Only Level 3 provides data to make the necessary distinctions. For the gasoline handling and solvent use sources, on Fig. 4-8, there is no provision for making a separation of the emission contributions. The nature of the sources (i.e., small and generally treated as area sources) renders this situation more tolerable.

Another possibility for projecting emissions is given in Reference 4. This procedure relies on the utilization of land-use-based emission factors rather than source-specific emission rates. This procedure has been tried in several places with varying success. It is significantly less detailed and subject to more error than the methods described here.

4.6 ESTIMATING SOURCE CONTRIBUTIONS

When a projection technique other than Level 3 is used to forecast emissions, then estimates of the contributions from new, modified, and existing sources can be made. The most frequently encountered situation is one in which the growth rate for the industry category is specified by planning data without regard to whether this will entail utilization of existing capacity, modifications to increase production capacity, or development of new facilities. The projected activity is then computed by:

$$\text{Projected Activity} = \text{Existing Capacity} \times \text{Growth Factor} \tag{4-4}$$

A first-order approximation to the source contributions is that all growth will occur via modifications to existing facilities or via new facilities. The implicit assumption is that existing capacity is being utilized at its maximum rate. The calculation procedure is the following:

$$\text{Activity from New Sources and Modified Existing Sources} = \text{Projected Activity} - \text{Existing Activity} \tag{4-5}$$

In computing emissions, the new and modified source activity would be subject to federal New Source Performance Standards or more stringent state standards (if applicable), while the existing activity would be subject to existing regulations. The calculation is the following:

$$\text{Emissions} = \text{Activity from New and Modified Sources} \times \text{NSPS or more stringent State Standards} + \text{Existing Activity} \times \text{Existing Regulations} \tag{4-6}$$

A further refinement of this estimate can be made if some information on facility retirements is known. In this case, the existing activity is reduced by the retirements. The new and modified source activity is increased by the corresponding amount and the activity calculation becomes:

$$\text{Activity from New and Modified Sources} = \text{Projected Activity} - [\text{Existing Activity} - \text{Retirements}] \tag{4-7}$$

Note that this assumes that total industrial capacity remains the same. Further detail to improve the disaggregation would probably not be available except from a Level 3 analysis. It is important to note that these calculations are carried out over a series of time increments that span the air quality analysis time frame. The application of growth, retirement, and new source standards may take place at discreet points in that span and should be accounted for. In reality, this amounts to nothing more than repeating the

calculation for every year using the previous year as the baseline and, at each point, reevaluating the distribution and the applicability of standards. Where parameters vary continuously or where there is no change for several consecutive years, the computations can be shortened. Mathematically, the entire procedure can be expressed as follows:

In the baseline year:

$$E_o = P_o \, (EF)_e \tag{4-8}$$

where E_o are the emissions for the base year, 0; P_o is the existing activity for the source category (e.g., steel) in year 0; and $(EF)_e$ is the emission factor considering only existing regulations and control equipment.

In the first projection year:

$$P_1 = P_0 \, G_{01} \tag{4-9}$$

$$E_1 = P_1 \, (EF)_e = P_0 \, G_{01} \, (EF)_e \tag{4-10}$$

where P_1 is the projected process activity in this first year, G_{01} is the growth factor between the base year and the first year. Note that the emission factor is unchanged since no change in regulations has been assumed to take place.

In the second projection year:

$$\begin{aligned} P_2 = P_1 \, G_{12} &= P_0 \, G_{01} \, G_{12} \\ &= P_0 \, G^2 \text{ (if the growth factor is constant)} \end{aligned} \tag{4-11}$$

$$E_2 = P_2 \, (EF)_e = P_0 \, G^2 \, (EF)_e \tag{4-12}$$

where G_{12} is the growth factor from year 1 to year 2. Note the simplification if the growth rate is constant. Note also that the emission factor is still unchanged.

In any year, k, prior to the promulgation of a more stringent standard for new source:

$$P_k = P_{k-1}\, G_{k,k-1} = P_0 (G_{01}\, G_{12} \cdots G_{k,k-1})$$

$$= P_0\, G^k \text{ (if the growth rate is constant)} \qquad (4\text{-}13)$$

$$E_k = P_k\, (EF)_e = P_0\, G^k\, (EF)_e \qquad (4\text{-}14)$$

This is a general equation suitable for all years prior to the setting of a new source standard. A disaggregation of source contributions is not necessary since all sources are under the same regulation.

In the year, ℓ, in which a new source standard becomes effective:

$$(P_\ell)_{total} = P_{\ell-1}\, G_{\ell-1,\ell} = P_0\, G^\ell \text{ (for constant growth rate)} \qquad (4\text{-}15)$$

This must be disaggregated into contributions from existing sources and new and modified sources. Using the assumption that the growth occurs entirely at new or modified facilities:

$$(P_\ell)_{\substack{new\ +\\ modified}} = (P_\ell)_{total} - (P_{\ell-1})_{total}$$

$$= P_0\, (G^\ell - G^{\ell-1})$$

$$= P_0\, G^{\ell-1}\, (G-1)$$

$$= P_{\ell-1}\, (G-1) \qquad (4\text{-}16)$$

Emissions are then computed as:

$$E_\ell = P_{\ell-1}\, (EF)_e + (P_\ell)_{\substack{new\ +\\ modified}}\, (EF)_n$$

$$= P_{\ell-1}\, [(EF)_e + (G-1)(EF)_n]$$

$$= P_0\, G^{\ell-1}\, [(EF)_e + (G-1)(EF)_n] \qquad (4\text{-}17)$$

where $(EF)_n$ is the emission factor under the new source standard.

In the next year after a promulgated standard (year ℓ+1):

$$P_{\ell+1} = P_\ell \, G_{\ell,\ell+1} = P_0 \, G^{\ell+1} \tag{4-18}$$

Using the same assumptions that all growth is at new or modified sources:

$$\begin{aligned}
(P_{\ell+1})_{\substack{\text{new +}\\ \text{modified}}} &= (P_{\ell+1})_{\text{total}} - (P_{\ell-1})_{\text{total}} \\
&= P_0 \, (G^{\ell+1} - G^{\ell-1}) \\
&= P_0 \, G^{\ell-1} \, (G^2 - 1) \\
&= P_{\ell-1} \, (G^2 - 1)
\end{aligned} \tag{4-19}$$

Note that the last term of the equation implies that the existing source activity is frozen at that level that existed in the year prior to the promulgation of the standard (i.e., year ℓ-1). The emissions are then computed as:

$$\begin{aligned}
E_{\ell+1} &= P_{\ell-1} \, (EF)_e + (P_{\ell+1})_{\substack{\text{new +}\\ \text{modified}}} \, (EF)_n \\
&= P_{\ell-1} \, (EF)_e + P_{\ell-1} \, (G^2 - 1)(EF)_n \\
&= P_{\ell-1} \, [(EF)_e + (G^2 - 1)(EF)_n] \\
&= P_0 \, G^{\ell-1} \, [(EF)_e + (G^2 - 1)(EF)_n]
\end{aligned} \tag{4-20}$$

At any year after the promulgation of a new source standard (year ℓ+p), the general equation is:

$$P_{\ell+p} = P_0 \, G^{\ell+p} \tag{4-21}$$

With the same distribution assumption:

$$(P_{\ell+p})_{\substack{\text{new +}\\ \text{modified}}} = (P_{\ell+p})_{\text{total}} - (P_{\ell-1})_{\text{total}}$$

$$= P_0 \, (G^{\ell+p} - G^{\ell-1})$$

$$= P_0 \, G^{\ell-1} \, (G^{p+1} - 1)$$

$$= P_{\ell-1} \, (G^{p+1} - 1) \qquad (4\text{-}22)$$

Emissions are computed by:

$$E_{\ell+p} = P_{\ell-1} \, (EF)_e + (P_{\ell+p})_{\substack{\text{new +}\\ \text{modified}}} \, (EF)_n$$

$$= P_{\ell-1} \, (EF)_e + P_{\ell-1} \, (G^{p+1} - 1) \, (EF)_n$$

$$= P_{\ell-1} \, [(EF)_e + (G^{p+1} - 1) \, (EF)_n]$$

$$= P_0 \, G^{\ell-1} \, [(EF)_e + (G^{p+1} - 1) \, (EF)_n] \qquad (4\text{-}23)$$

In summary, the key equations are the following:

$$E_k = P_0 \, G^k \, (EF)_e \qquad (4\text{-}24)$$

for year k prior to the setting of a new source standard

$$E_{\ell+p} = P_0 \, G^{\ell-1} \, [(EF)_e + (G^{p+1} - 1) \, (EF)_n] \qquad (4\text{-}25)$$

for year ℓ+p where a new source standard is set in year ℓ

and the assumptions that are implicit are (1) a constant growth rate and (2) all growth is at new and modified sources. If there are data on capacity retirements and/or unused capacity it can be incorporated into this framework easily; the existing capacity is either reduced (in the case of retirements)

or increased (in the case of utilization of currently unused capacity) by the appropriate amounts.

Equations 4-24 and 4-25 produce exactly the same results as the equations given in the supplement to Reference 13 recently issued by EPA.[28] Some algebraic manipulations will illustrate the compatibility of the two descriptions. For example, the term RF in the Reference 28 description is the emission reduction factor for new source regulations. This is equivalent to $(EF)_n/(EF)_e$ in this description. The Reference 28 term NGR is the growth rate for sources covered by new source regulations and is equivalent to $(G^{p+1} - 1)$ in this formulation. The term CGR, which is the growth rate for increasing production activity up to full capacity, and the term RR, which is the retirement rate, are not used in the simplified formulation presented here.

A detailed description of the formulation described here is given in Appendix G.

4.7 FEDERAL NEW SOURCE PERFORMANCE STANDARDS

The implementation of federal New Source Performance Standards (NSPS) has a marked effect on the computation of future emissions. To date, NSPS have been promulgated for only a few of the 250 odd possible candidate source categories. The issued supplement to Reference 13 contains preliminary estimates of the standards that will be set in the time period of the air quality analysis.[28] These estimates are not to be treated as promulgated regulations and are only to be used as guidelines of the expected emission levels. The Regional Office should be consulted for the latest available information prior to conducting the analysis.

In determining the effect of NSPS on an industry or on a specific facility, Reference 7 gives the following guidelines:

NSPS are applicable to:

- Replacement of obsolete equipment at an existing plant.
- Additions of new equipment at an existing plant.
- All equipment at a new plant.

NSPS are not applicable to:

- Existing equipment at a plant whether used or not.

In the terminology of the previous section, the replacement of obsolete equipment and the addition of new equipment constitutes a plant modification, while the new plant is a new source.

4.8 SUMMARY OF COUNTY X DATA

Table 4.1 summarizes the emission projections for County X. Tables 4.2 to 4.4 give the emission projections for 1975, 1980, and 1985, respectively, in the NER format described in Reference 7. The emission projections account for existing state regulations, for available compliance information, and for those federal New Source Performance Standards that are expected to apply prior to 1985. It is evident that countywide emissions are expected to increase by about 40% between 1975 and 1985. The largest increases occur in the mineral products industry, industrial fuel combustion, and the primary metals industry. The incineration and miscellaneous (fugitive dust in this case) categories sustain smaller increases but still account for substantial portions of the total emissions.

Table 4-1. County X Particulate Emission Projections

	Emissions[a] (tons/year)												
	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Industrial Process													
Chemical Manufacturing	1	1	1	1	2	2	2	2	2	2	2	2	2
Food/Agriculture	5	5	5	5	6	6	6	6	6	6	7	7	7
Primary Metals	6,274	6,599	6,923	7,248	7,572	7,897	8,221	8,546	8,717	8,888	9,058	9,229	9,400
Secondary Metals	41	43	45	47	50	52	54	56	57	59	60	62	63
Mineral Products	4,476	5,319	6,161	7,004	7,846	8,689	9,531	10,374	10,569	10,764	10,958	11,153	11,348
All Others	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	10,797	11,967	13,135	14,305	15,476	16,646	17,814	18,984	19,351	19,719	20,085	20,453	20,820
Fuel Combustion													
Residential	229	242	254	267	279	292	304	317	330	343	356	369	382
Commercial/Institutional	228	232	235	239	243	247	250	254	259	265	270	276	281
Industrial	3,611	3,858	4,104	4,351	4,598	4,845	5,091	5,338	5,586	5,834	6,082	6,330	6,578
Total	4,068	4,332	4,593	4,857	5,120	5,384	5,645	5,909	6,175	6,442	6,708	6,975	7,241
Transportation	821	833	845	857	869	881	893	905	929	952	976	999	1,023
Electric Generation	0	0	0	0	0	0	0	0	0	0	0	0	0
Incineration	7,922	8,059	8,196	8,333	8,469	8,606	8,743	8,880	9,052	9,224	9,395	9,567	9,739
Miscellaneous	5,916	5,916	5,916	5,916	5,916	5,916	5,916	5,916	5,916	5,916	5,916	5,916	5,916
GRAND TOTAL	29,524	31,107	32,685	34,268	35,850	37,433	39,011	40,594	41,423	42,253	43,080	43,910	44,739

[a]Based on existing state regulations and expected federal New Source Performance Standards.

Table 4-2. County X Projected Emissions, 1975

COUNTY X

YEAR 1975

County Base Year Emissions Report

SOURCE				EMISSIONS, TONS PER YEAR				
				PART	SOX	NOX	HC	CO
FUEL COMBUSTION EXTERNAL	RESIDENTIAL FUEL (AREA)	ANTHRACITE COAL						
		BITUMINOUS COAL		20				
		DISTILLATE OIL		20				
		RESIDUAL OIL						
		NATURAL GAS		214				
		WOOD						
		TOTAL		254				
	ELECTRIC GENERATION (POINT)	ANTHRACITE COAL						
		BITUMINOUS COAL						
		LIGNITE						
		RESIDUAL OIL						
		DISTILLATE OIL						
		NATURAL GAS						
		PROCESS GAS						
		COKE						
		SOLID WASTE COAL						
		TOTAL						
	INDUSTRIAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	76				
			POINT	3074				
		LIGNITE	POINT					
		RESIDUAL OIL	AREA	2				
			POINT	648				
		DISTILLATE OIL	AREA	121				
			POINT	1				
		NATURAL GAS	AREA	174				
			POINT	9				
		PROCESS GAS	AREA					
			POINT					
		COKE	POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		BAGASSE	POINT					
		OTHER	POINT					
		TOTAL	AREA	373				
			POINT	3732				

Table 4-2. County X Projected Emissions, 1975 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
FUEL COMBUSTION EXTERNAL (CONTINUED)	COMMERCIAL INSTITUTIONAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	64				
			POINT					
		LIGNITE	POINT					
		RESIDUAL OIL	AREA					
			POINT					
		DISTILLATE OIL	AREA	32				
			POINT					
		NATURAL GAS	AREA	141				
			POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		OTHER	POINT					
		TOTAL	AREA	235				
			POINT					
	OTHER		POINT					
	TOTAL EXTERNAL COMBUSTION		AREA	862				
			POINT	3732				
FUEL COMBUSTION INTERNAL	ELECTRIC GENERATION	DISTILLATE OIL						
		NATURAL GAS						
		DIESEL						
		OTHER						
		TOTAL						
	INDUSTRIAL FUEL	DISTILLATE OIL						
		NATURAL GAS						
		GASOLINE						
		DIESEL						
		OTHER						
		TOTAL						
	COMMERCIAL INSTITUTIONAL FUEL	DIESEL						
		TOTAL						
	ENGINE TESTING	AIRCRAFT						
	TOTAL INTERNAL COMBUSTION							
TOTAL FUEL COMBUSTION		AREA		862				
		POINT		3732				

Table 4-2. County X Projected Emissions, 1975 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
INDUSTRIAL PROCESS (POINT)	CHEMICAL MANUFACTURING			1				
	FOOD AGRICULTURE			5				
	PRIMARY METAL			6923				
	SECONDARY METALS			45				
	MINERAL PRODUCTS			6161				
	PETROLEUM INDUSTRY							
	WOOD PRODUCTS							
	PROCESS EVAPORATION							
	METAL FABRICATION							
	LEATHER PRODUCTS							
	TEXTILE MANUFACTURING							
	INPROCESS FUEL							
	OTHER NOT CLASSIFIED							
	TOTAL			13135				
SOLID WASTE DISPOSAL	GOVERNMENT (POINT)	MUNIC INCIN						
		OPEN BURNING						
		OTHER		10				
		TOTAL		10				
	RESIDENTIAL (AREA)	ON SITE INCIN						
		OPEN BURNING						
		TOTAL						
	COMMERCIAL INSTITUTIONAL	ON SITE INCIN ERATION	AREA	948				
			POINT					
		OPEN BURNING	AREA	1761				
			POINT					
		APARTMENT	POINT					
		OTHER	AREA					
			POINT					
		TOTAL	AREA	2710				
			POINT					
	INDUSTRIAL	ON SITE INCIN ERATION	AREA	176				
			POINT	452				
		OPEN BURNING	AREA	4848				
			POINT					
		AUTO BODY INCIN	POINT					
		OTHER	POINT					
		TOTAL	AREA	5024				
			POINT	452				
	TOTAL SOLID WASTE DISPOSAL		AREA	7734				
			POINT	462				

Table 4-2. County X Projected Emissions, 1975 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
TRANSPORTATION (AREA)	LAND VEHICLES	GASOLINE	LIGHT DUTY	734				
			HEAVY DUTY	111				
			OFF HIGHWAY					
			TOTAL					
		DIESEL	HEAVY DUTY					
			OFF HIGHWAY					
			RAIL					
			TOTAL					
	AIRCRAFT	MILITARY						
		CIVIL						
		COMMERCIAL						
		TOTAL						
	VESSELS	BITUMINOUS COAL						
		DIESEL FUEL						
		RESIDUAL OIL						
		GASOLINE						
		TOTAL						
	GAS HANDLING EVAPORATION LOSS							
	TOTAL TRANSPORTATION			845				

Table 4-2. County X Projected Emissions, 1975 (Continued)

SOURCE			PART	SOX	NOX	HC	CO
MISCELLANEOUS (AREA)	SOLVENT EVAPORATION	INDUSTRIAL SOURCES (AREA)					
		DRY CLEANING					
	FIRES	STRUCTURAL					
		FROST CONTROL					
		SLASH BURNING					
		WILD FOREST					
		AGRICULTURAL					
	DUST CAUSED BY HUMAN AGITATION OF THE AIR	UNPAVED ROADS	1439				
		UNPAVED AIRSTRIPS					
		PAVED ROADS					
		MINERAL PROCESSING					
		TILLING ACTIVITIES	877				
		LOADING CRUSHED ROCK SAND GRAVEL					
		CONSTRUCTION	3600				
	AIRBORNE DUST CAUSED BY NATURAL WINDS	STORAGE PILES					
		TILLED LAND					
		UNTILLED LAND					
		Total Miscellaneous	5916				
GRAND TOTAL		AREA	15357				
		POINT	17329				

Table 4-3. County X Projected Emissions, 1980

COUNTY X

YEAR ~~1980~~

County Base Year Emissions Report

SOURCE				EMISSIONS TONS PER YEAR				
				PART	SOX	NOX	HC	CO
FUEL COMBUSTION EXTERNAL	RESIDENTIAL FUEL (AREA)	ANTHRACITE COAL						
		BITUMINOUS COAL		24				
		DISTILLATE OIL		24				
		RESIDUAL OIL						
		NATURAL GAS		269				
		WOOD						
		TOTAL		317				
	ELECTRIC GENERATION (POINT)	ANTHRACITE COAL						
		BITUMINOUS COAL						
		LIGNITE						
		RESIDUAL OIL						
		DISTILLATE OIL						
		NATURAL GAS						
		PROCESS GAS						
		COKE						
		SOLID WASTE COAL						
		TOTAL						
	INDUSTRIAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	99				
			POINT	3995				
		LIGNITE	POINT					
		RESIDUAL OIL	AREA	3				
			POINT	843				
		DISTILLATE OIL	AREA	157				
			POINT	2				
		NATURAL GAS	AREA	226				
			POINT	13				
		PROCESS GAS	AREA					
			POINT					
		COKE	POINT					
		WOOD	AREA					
			POINT					
		PETROLEUM GAS	POINT					
		COKE	POINT					
		OTHER	POINT					
		TOTAL	AREA	485				
			POINT	4853				

Table 4-3. County X Projected Emissions, 1980 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
FUEL COMBUSTION EXTERNAL (CONTINUED)	COMMERCIAL INSTITUTIONAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	71				
			POINT					
		LIGNITE	POINT					
		RESIDUAL OIL	AREA					
			POINT					
		DISTILLATE OIL	AREA	34				
			POINT					
		NATURAL GAS	AREA	149				
			POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		OTHER	POINT					
		TOTAL	AREA	254				
			POINT					
	OTHER		POINT					
	TOTAL EXTERNAL COMBUSTION		AREA	1056				
			POINT	4853				
FUEL COMBUSTION INTERNAL	ELECTRIC GENERATION	DISTILLATE OIL						
		NATURAL GAS						
		DIESEL						
		OTHER						
		TOTAL						
	INDUSTRIAL FUEL	DISTILLATE OIL						
		NATURAL GAS						
		GASOLINE						
		DIESEL						
		OTHER						
		TOTAL						
	COMMERCIAL INSTITUTIONAL FUEL	DIESEL						
		TOTAL						
	ENGINE TESTING	AIRCRAFT						
	TOTAL INTERNAL COMBUSTION							
TOTAL FUEL COMBUSTION		AREA		1056				
		POINT		4853				

Table 4-3. County X Projected Emissions, 1980 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
INDUSTRIAL PROCESS (POINT)	CHEMICAL MANUFACTURING			2				
	FOOD AGRICULTURE			6				
	PRIMARY METAL			8546				
	SECONDARY METALS			56				
	MINERAL PRODUCTS			10374				
	PETROLEUM INDUSTRY							
	WOOD PRODUCTS							
	PROCESS EVAPORATION							
	METAL FABRICATION							
	LEATHER PRODUCTS							
	TEXTILE MANUFACTURING							
	INPROCESS FUEL							
	OTHER NOT CLASSIFIED							
	TOTAL			18984				
SOLID WASTE DISPOSAL	GOVERNMENT (POINT)	MUNIC INCIN						
		OPEN BURNING						
		OTHER		14				
		TOTAL		14				
	RESIDENTIAL (AREA)	ON SITE INCIN						
		OPEN BURNING						
		TOTAL						
	COMMERCIAL INSTITUTIONAL	ON SITE INCIN ERATION	AREA	1027				
			POINT					
		OPEN BURNING	AREA	1907				
			POINT					
		APARTMENT	POINT					
		OTHER	AREA					
			POINT					
		TOTAL	AREA	2934				
			POINT					
	INDUSTRIAL	ON SITE INCIN ERATION	AREA	191				
			POINT	492				
		OPEN BURNING	AREA	5249				
			POINT					
		AUTO BODY INCIN	POINT					
		OTHER	POINT					
		TOTAL	AREA	5440				
			POINT	492				
	TOTAL SOLID WASTE DISPOSAL		AREA	8374				
			POINT	506				

Table 4-3. County X Projected Emissions, 1980 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
TRANSPORTATION (AREA)	LAND VEHICLES	GASOLINE	LIGHT DUTY	786				
			HEAVY DUTY	119				
			OFF HIGHWAY					
			TOTAL					
		DIESEL	HEAVY DUTY					
			OFF HIGHWAY					
			RAIL					
			TOTAL					
	AIRCRAFT	MILITARY						
		CIVIL						
		COMMERCIAL						
		TOTAL						
	VESSELS	BITUMINOUS COAL						
		DIESEL FUEL						
		RESIDUAL OIL						
		GASOLINE						
		TOTAL						
	GAS HANDLING EVAPORATION LOSS							
	TOTAL TRANSPORTATION			905				

Table 4-3. County X Projected Emissions, 1980 (Continued)

SOURCE			PART	SOX	NOX	HC	CO
MISCELLANEOUS (AREA)	SOLVENT EVAPORATION	INDUSTRIAL SOURCES (AREA)					
		DRY CLEANING					
	FIRES	STRUCTURAL					
		FROST CONTROL					
		SLASH BURNING					
		WILD FOREST					
		AGRICULTURAL					
	DUST CAUSED BY HUMAN AGITATION OF THE AIR	UNPAVED ROADS	1439				
		UNPAVED AIRSTRIPS					
		PAVED ROADS					
		MINERAL PROCESSING					
		TILLING ACTIVITIES	877				
		LOADING CRUSHED ROCK SAND GRAVEL					
		CONSTRUCTION	3600				
	AIRBORNE DUST CAUSED BY NATURAL WINDS	STORAGE PILES					
		TILLED LAND					
		UNTILLED LAND					
		Total Miscellaneous	5916				
GRAND TOTAL	AREA		16251				
	POINT		24343				

Table 4-4. County X Projected Emissions, 1985

COUNTY X

YEAR 1985

County Base Year Emissions Report

SOURCE				EMISSIONS TONS PER YEAR				
				PART	SOX	NOX	HC	CO
FUEL COMBUSTION EXTERNAL	RESIDENTIAL FUEL (AREA)	ANTHRACITE COAL						
		BITUMINOUS COAL		29				
		DISTILLATE OIL		29				
		RESIDUAL OIL						
		NATURAL GAS		324				
		WOOD						
		TOTAL		382				
	ELECTRIC GENERATION (POINT)	ANTHRACITE COAL						
		BITUMINOUS COAL						
		LIGNITE						
		RESIDUAL OIL						
		DISTILLATE OIL						
		NATURAL GAS						
		PROCESS GAS						
		COKE						
		SOLID WASTE COAL						
		TOTAL						
	INDUSTRIAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	122				
			POINT	4926				
		LIGNITE	POINT					
		RESIDUAL OIL	AREA	4				
			POINT	1038				
		DISTILLATE OIL	AREA	193				
			POINT	2				
		NATURAL GAS	AREA	280				
			POINT	13				
		PROCESS GAS	AREA					
			POINT					
		COKE	POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		BAGASSE	POINT					
		OTHER	POINT					
		TOTAL	AREA	599				
			POINT	5979				

Table 4-4. County X Projected Emissions, 1985 (Continued)

SOURCE				PART	SOx	NOx	HC	CO
FUEL COMBUSTION EXTERNAL (CONTINUED)	COMMERCIAL INSTITUTIONAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	78				
			POINT					
		LIGNITE	POINT					
		RESIDUAL OIL	AREA					
			POINT					
		DISTILLATE OIL	AREA	38				
			POINT					
		NATURAL GAS	AREA	165				
			POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		OTHER	POINT					
		TOTAL	AREA	281				
			POINT					
	OTHER		POINT					
	TOTAL EXTERNAL COMBUSTION		AREA	1262				
			POINT	5979				
FUEL COMBUSTION INTERNAL	ELECTRIC GENERATION	DISTILLATE OIL						
		NATURAL GAS						
		DIESEL						
		OTHER						
		TOTAL						
	INDUSTRIAL FUEL	DISTILLATE OIL						
		NATURAL GAS						
		GASOLINE						
		DIESEL						
		OTHER						
		TOTAL						
	COMMERCIAL INSTITUTIONAL FUEL	DIESEL						
		TOTAL						
	ENGINE TESTING	AIRCRAFT						
	TOTAL INTERNAL COMBUSTION							
TOTAL FUEL COMBUSTION		AREA		1262				
		POINT		5979				

Table 4-4. County X Projected Emissions, 1985 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
INDUSTRIAL PROCESS (POINT)	CHEMICAL MANUFACTURING			2				
	FOOD AGRICULTURE			7				
	PRIMARY METAL			9400				
	SECONDARY METALS			63				
	MINERAL PRODUCTS			11348				
	PETROLEUM INDUSTRY							
	WOOD PRODUCTS							
	PROCESS EVAPORATION							
	METAL FABRICATION							
	LEATHER PRODUCTS							
	TEXTILE MANUFACTURING							
	INPROCESS FUEL							
	OTHER NOT CLASSIFIED							
	TOTAL			20820				
SOLID WASTE DISPOSAL	GOVERNMENT (POINT)	MUNIC. INCIN.						
		OPEN BURNING						
		OTHER		17				
		TOTAL		17				
	RESIDENTIAL (AREA)	ON SITE INCIN.						
		OPEN BURNING						
		TOTAL						
	COMMERCIAL INSTITUTIONAL	ON SITE INCIN. ERATION	AREA	1127				
			POINT					
		OPEN BURNING	AREA	2093				
			POINT					
		APARTMENT	POINT					
		OTHER	AREA					
			POINT					
		TOTAL	AREA	3220				
			POINT					
	INDUSTRIAL	ON SITE INCIN. ERATION	AREA	209				
			POINT	520				
		OPEN BURNING	AREA	5773				
			POINT					
		AUTO BODY INCIN.	POINT					
		OTHER	POINT					
		TOTAL	AREA	5982				
			POINT	520				
	TOTAL SOLID WASTE DISPOSAL		AREA	9202				
			POINT	537				

Table 4-4. County X Projected Emissions, 1985 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
TRANSPORTATION (AREA)	LAND VEHICLES	GASOLINE	LIGHT DUTY	889				
			HEAVY DUTY	134				
			OFF HIGHWAY					
			TOTAL					
		DIESEL	HEAVY DUTY					
			OFF HIGHWAY					
			RAIL					
			TOTAL					
	AIRCRAFT	MILITARY						
		CIVIL						
		COMMERCIAL						
		TOTAL						
	VESSELS	BITUMINOUS COAL						
		DIESEL FUEL						
		RESIDUAL OIL						
		GASOLINE						
		TOTAL						
	GAS HANDLING EVAPORATION LOSS							
	TOTAL TRANSPORTATION			1023				

Table 4-4. County X Projected Emissions, 1985 (Continued)

SOURCE			PART	SOX	NOX	HC	CO
MISCELLANEOUS (AREA)	SOLVENT EVAPORATION	INDUSTRIAL SOURCES (AREA)					
		DRY CLEANING					
	FIRES	STRUCTURAL					
		FROST CONTROL					
		SLASH BURNING					
		WILD FOREST					
		AGRICULTURAL					
	DUST CAUSED BY HUMAN AGI TATION OF THE AIR	UNPAVED ROADS	1439				
		UNPAVED AIRSTRIPS					
		PAVED ROADS					
		MINERAL PROCESSING					
		TILLING ACTIVITIES	877				
		LOADING CRUSHED ROCK, SAND, GRAVEL					
		CONSTRUCTION	3600				
	AIRBORNE DUST CAUSED BY NATURAL WINDS	STORAGE PILES					
		TILLED LAND					
		UNTILLED LAND					
		Total Miscellaneous	5916				
GRAND TOTAL	AREA		17403				
	POINT		27336				

PROBLEM 4-1

Estimate the future particulate emissions for the clay products industry in County X in the period 1975 to 1985. Assume the following information is known.

There are currently two clay products plants in County X with the following characteristics:

Company ABC - current production is 35,000 tons of finished product per year.

Company DEF - current production is 15,000 tons of finished product per year.

Regional planning data estimates a growth in demand for the product from the region of 2.5% per year. A federal New Source Performance Standard is expected in 1983 that will limit emissions to 4.5 lb per ton of finished product. The current state regulation is 10 lb per ton. Also, it is known that Company DEF is scheduled to shut down its current plant at the end of 1984. Assume the air quality analysis is being performed for 1980 and 1985 and the baseline inventory is for 1973.

5. ALLOCATION OF EMISSIONS

To this point, the focus of the emission inventory portion of the analysis has been to generate the emission pattern on a county-by-county basis for the region under study. Prior experience with air quality management has shown the following:

> Countywide spatial resolution of emissions is too coarse for particulates, SO_2, and CO.
>
> Countywide spatial resolution of emissions is too fine for oxidants, nitrogen oxides, and hydrocarbons.

The latter three pollutants are reactive under ambient conditions and their impacts on air quality can be felt at large distances from the emitting sources. For this reason, there is no pressing need to develop an analysis with finer spatial resolution for these pollutants. Rather, they will be treated on a regionwide basis. The exception to this general guideline is when an analysis of one or more of these pollutants will be made with a photochemical dispersion model. In this case, the model requires, as input, a better spatial description of emissions than is available from countywide data and the same allocation procedures that will be described for the other pollutants can be used.

For particulates, SO_2, and CO, the effects of individual sources are much more localized in impact and an adequate analysis and control strategy development relies on a fine spatial resolution of emissions. The objective of this section is to describe techniques that can be used to achieve this resolution.

These procedures should not be viewed as necessarily separate and distinct from the development of the baseline inventory or the estimation of future emissions. In many instances these techniques can be used in parallel rather than in series with the previous methods.

5.1 DETERMINATION OF GEOGRAPHIC SCALE

The identification of the level of spatial resolution is a function of several variables:

Available data
Anticipated problem areas

Anticipated problem sources
Applicability to modeling
Applicability to strategies
Resources available

The principle constraint on spatial resolution is, of course, the available data. If the information is on too coarse a geographical scale, then an extensive effort is usually required to improve the data base. In general, this will be required only in special circumstances and only for special sources. It is not unusual to have data from different source categories with different spatial resolutions. For example, population data may be available on census tract subcounty resolution, while transportation data may be on planning district resolution. This presents no special problems since all sources eventually will be mapped into a master grid.

The spatial resolution should be fine enough to distinguish special problem areas and special problem sources. As an illustration, it is not possible to treat a major metropolitan city in its entirety. The spatial resolution should be able to distinguish the Central Business District (CBD) from industrial parks and from residential neighborhoods.

The use of dispersion models dictates certain limits on the size of sources and hence on the spatial resolution. Although the models can theoretically treat any size areas, the accuracy suffers if the sources are too large and computation expense suffers if they are too small. This consideration becomes more significant when the master grid is developed and will be discussed later.

The applicability of control strategies is an important consideration and is one of the prime reasons for using a subcounty resolution. In general, control strategies may not be appropriate for application to an entire county across the board. From an enforceability standpoint, however, a control strategy will, most likely, be applied within political boundaries (as opposed to arbitrary areas) and the analysis should be sensitive to these considerations.

Finally, the resources available will dictate the level of spatial disaggregation that can be tolerated. The large number of calculations required for each subcounty area dictates the need for computer assistance if any significant number of areas are to be considered.

5.2 ALLOCATION PARAMETERS

5.2.1 Population

There are a number of sources whose emission distribution may be linked directly to the population distribution. For each county there are several different geographical descriptions of population distribution, any one of which may be used. The Census of Population and Housing provides the most widely available demographic data, although some areas have regional planning commissions, which normally embellish the resolution of the Census data.

The types of subcounty areas for which demographic data are normally available include municipalities, census tracts, Master Enumeration Districts, regional planning districts, and townships. In every area there are population data available on at least a municipality basis. This information is tabulated in the Census of Population for all places containing a population of 2500 or more. The geographical location of these municipalities may be found either in the census publications or on regional maps. It should be noted, however, that the municipalities may not cover an entire county, since there may be extensive unincorporated areas. In these cases, the total of the municipality populations is subtracted from the total county population (also tabulated by the Census Bureau) to determine the residual county population (the number of people living outside of municipal boundaries). This selection of subareas will generally result in delineating only a small number of districts within each county, and population-based allocations can, therefore, be easily handled without a computer.

For most large, urbanized areas, the region is subdivided into tracts by the Census Bureau. These tracts, while lying within county boundaries, do not necessarily lie along municipal boundaries and may overlap several political jurisdictions. The tracts are large in the less densely populated areas and small in centers of population concentration. Because tracts are delineated according to population density, they portray the distribution of a county's population at a high degree of resolution. Nevertheless, choice of census tracts as the population-based subareas must be made with careful consideration. In some regions the number of tracts, though larger than the number of municipalities, is still small enough to be managed without computer assistance (the Atlanta SMSA has 238 tracts). On the other hand, some regions

have a large number of tracts, which make hand computations unwieldy (the Chicago SMSA has over 1500 tracts). Census tracts should therefore be used as subcounty areas only when sufficient computational resources are available and good detail is needed. In any case, the Bureau of the Census publishes the tract information both in printed form and on computer-compatible magnetic tape.

Master Enumeration Districts are essentially the same as census tracts in areas that are tracted and have other definitions in untracted areas. Data for these districts are tabulated on computer-compatible magnetic tape, available from the Census Bureau. A set of computer programs has been written to enable one to process this information and to develop a grid system for the allocation of area source emissions. These programs and gridding procedures are documented in Ref. 8.

Areas in which there are active regional planning commissions will usually be subdivided into planning districts that the commissions use for displaying data. In some areas, these planning districts lie along municipal or census tract boundaries. In other areas, they are drawn up to meet the specific requirements of a particular commission and do not correspond to any other subarea definition.

In most areas of the country, a political jurisdiction, referred to as a township, is superimposed on existing municipal jurisdictions. The townships are normally square-gridded with 36 square-mile sections in each. These townships can be used as regional planning districts, as in Northern Illinois.

The main conclusion to be drawn from this discussion is that there are a variety of subcounty areas for which population distribution information is displayed. In any given region, there may be more than one subarea set. Choice of the appropriate set of subareas for use in allocating emissions is based on identifying which one contains the most detailed set of information and yet is manageable within the resources of the planning agency charged with maintaining air quality. It is recommended that the subareas to be used for the transportation allocation and the commercial/institutional-industrial allocation be investigated prior to making a final choice of the data resolution needed to allow for the possibility that one subarea set may provide information more appropriate for all stages of the air quality analysis system.

5.2.2 Transportation

As with the population-based subcounty areas, there are a number of subarea sets available for describing the distribution of transportation systems. In some areas of the country, the transportation planning agency may use one of the regional planning grids for developing its data base, in which case the population-based subareas and the transportation-based subareas can be selected as being one and the same.

In other regions, the transportation planning grid may be developed separately. This separation presents no unusual problems in the allocation procedure, and there is no need at this point to try to convert one grid system to another.

Some regions will have no grid system that is used for transportation-related data display and all that will be available will be highway department road maps. In most areas where this situation prevails, vehicle count data will be available only for the major expressways and busy arterials.

In some instances, however, the state transportation department will have developed traffic data on a link-by-link basis as part of the Continuing, Comprehensive, and Coordinated (3-C) transportation planning process. The links will generally be described by the UTM coordinates for their end points and have vehicle count data on them.

5.2.3 Commercial/Institutional, Industrial, and Electric Generation

The most definitive form of spatial resolution of these source categories is the location of point sources in which their specific coordinates are specified. The display of area source data is generally in one of the forms previously described, such as census districts, regional planning districts, or townships. An additional information display may be a land-use map of the area on which the various land uses are coded to indicate the distribution of activity. While this type of presentation does not rely on a grid network, it can nevertheless provide useful data for the analysis by describing the spatial development of the land in the area. This data may be converted to a grid network using the techniques described in Reference 29.

5.3 ALLOCATION PROCEDURES

There are basically three procedures for determining spatial allocations of emission-producing activity:

Locate the activity directly from available data,

Develop a distribution function of activity using an allocation parameter (e.g., population), and

A combination of the above procedures.

Reference 13 outlines the recommended procedures for these methods as applicable to each of the source categories. The sources that can be spatially located directly are:

Industrial point sources -- existing and some new,

Commercial/Institutional point sources -- existing and some new,

Electric generation -- existing and most new, and

Limited access highways -- existing and most new.

For all existing sources, the spatial coordinates are available from the emission inventory. (Although limited access highways are not normally specifically included in an emission inventory, their coordinates are easily determined from maps.) For industrial and commercial/institutional new sources, there is often only limited information available on new plant locations. Where these data are available, they can be used to identify source coordinates. For power plants, the location of new facilities is well documented in References 30 and 31. There may be uncertainty in the location of some new sites, but, in general, the utility planning horizon is long-range enough to identify most new installations. In a similar way, the location of most new limited access highways is sufficiently well documented (at least in terms of alternative possibilities) to enable their geographic location to be well defined.

Source activity that cannot be located directly can use a distribution function to allocate emissions. A simple model would start with the knowledge of the activity on a countywide basis and then distribute this activity to each subcounty area based on that area's proportion of some countywide para-

meter, such as population or employment. For example, if a county is divided into 20 subcounty areas and the 5th area contains 12% of the county's population, then all emission-producing activity that is related to population (e.g., solid waste disposal) can have 12% of the countywide emissions allocated to subarea 5. The types of distribution functions that can be developed include:

population
dwelling units
dwelling units by fuel use
employment
land use
area

An illustration of the effect of using different distribution functions is found in Appendix B of Reference 13 dealing with residential fuel combustion emissions. The three orders of allocation procedures illustrate the use of a population distribution function, a dwelling unit distribution function, and a fuel-use and building-size distribution function available for each subarea, respectively. In all three cases, the countywide total fuel use and emissions are the same. Use of the population and dwelling unit distributions give only slightly different results among the various subareas. The most detailed distribution, however, results in a change in the calculated emissions of 19% in the largest subarea (i.e., Atlanta).

The third type of allocation procedure is a combination of the specific location information and the distribution function. Its aim is to use whatever specific location data are available for a source category and allocate the remainder by some form of distribution function. Its prime utility is in allocating activity from new sources that cannot be placed with any degree of certainty. Starting with the computation of emissions on a countywide basis (with account taken of new source regulations where applicable), the procedure can take one of three paths with regard to locating new source emissions:

1. Assume all new source emissions occur at the same location as existing sources (i.e., growth-in-place).

2. Assume all new source emissions occur at new sites and allocate according to an employment or land-use distribution function.

3. Determine the mix between existing and new source activity and allocate accordingly.

The first method is the easiest since the location of the source activities are already known and are assumed to remain the same. It is also the least accurate since it does not reflect realistic development in most areas. The second and third methods are more accurate but require significantly more data.

In some situations it may be possible to utilize a sophisticated growth and development model to determine the spatial distribution of emissions. Models that can be used for this purpose are represented by the work of Lowry[32] and the Hackensack Meadowlands Project.[33] These models generally follow the third allocation procedure (i.e., combine existing locational information with distribution function approaches) but in a much more analytical way than the simple approaches described here. The experience and resources of the agency performing the air quality analysis will determine if this approach is useful.

PROBLEM 5-1

Using the previously calculated data for the clay products industry in County X (Problem 4-1), allocate these emissions to the ten subcounty areas defined by the planning commission data in Appendix D for 1980 and 1985. Company ABC is in Superdistrict 16 and Company DEF is in Superdistrict 15. Assume that both plants are currently operating at 100% capacity and that the allocation of new source emissions will be based on the growth in industrial land area in each superdistrict (see Table D-4 in Appendix D for a summary of this calculation). Tables 3.4-1 to 3.4-4 from Reference 13 (reproduced here as Figs. 5-1 to 5-4) may be used to structure the computation. Tables 3.4-1 and 3.4-2 may be filled in directly using the results of Problem 4-1. In using Table 3.4-3 note that the Employment Allocation Proportion is replaced by an industrial land use growth proportion.

Table 3.4-1

Point Source Industrial Process Emissions

A. County _____
B. Year _____
C. Allocation Order 1, 2, and 3

(1) Industrial Process Category	Source Identification					Process Emission Forecast (tons/yr)												
	(2) Name	(3) Process	(4) Subarea	(5) Coord.		(6)	(7) Part.		(8) SO_x		(9) CO		(10) HC		(11) NO_x		(12)	
				X	Y	GF**	Cont.	Emis.	Cont.	Emis.	Cont.	Emis.	Cont.	Emis.	Cont.	Emis.	Emp.*	

*Employment
**Growth Factor

Fig. 5-1. Point Source Industrial Process Emissions, Table 3.4-1 from Ref. 13

Table 3.4-2

Industrial Point and New Source Process Emissions by Process Category

A. County _____

B. Year _____

C. Allocation Order 2 and 3

(1) Industrial Process Category	Baseline Year Existing Point Sources						Forecast Year All Sources							Forecast Year Existing Point Sources						Forecast Year New Sources										
	(2) Part	(3) NO_x	(4) (2)	(5) (4)	(6) NO_x	(7) Emp*	(8) (4)**	(9) Part	(10) NO_x	(11) (2)	(12) (4)	(13) NO_x	(14) Emp*	(15) Part	(16) NO_x	(17) (2)	(18) (4)	(19) NO_x	(20) Emp*	(21) Part		(22) NO_x		(23) (2)		(24) (4)		(25) NO_x		(26) Emp*
																				Cont	Emis	Cont	Emis	Cont	Emis	Cont	Emis	Cont	Emis	
D. COUNTY TOTAL																														

* Employment

**Growth Factor

Fig. 5-2. Industrial Point and New Source Process Emissions by Process Category, Table 3.4-2 from Ref. 13

Table 3.4-3

Process Emissions by Process Category and Subarea

A. County _____
B. Subarea _____
C. Year _____
D. Allocation Order 2 and 3

Industrial Process Category (1)	Total Emp. (2)	Point Source Emp. (3)	New Source Emp. (4)	LAP* (5)	New Source Emissions (tons/yr)				
					(6) Part.	(7) SO_x	(8) CO	(9) HC	(10) NO_x
E. SUBAREA TOTAL									

*Employment Allocation Proportion = $\frac{\text{Subarea Category New Source Employment}}{\text{Total Category New Source Employment}}$

Fig. 5-3. Process Emissions by Process Category and Subarea, Table 3.4-3 from Ref. 13

Table 3.4-4

Industrial Point and New Source Process Emissions - Subarea Summary

A. County
B. Subarea
C. Year
D. Allocation Order 1, 2, and 3

Industrial Process Category (1)	Point Source Emissions							New Source Emissions						Total Emissions					
	(2) No. of Sources	(3) Emp.*	(4) Part.	(5) SO_2	(6) CO	(7) HC	(8) NO_2	(9) Emp.*	(10) Part.	(11) SO_2	(12) CO	(13) HC	(14) NO_2	(15) Emp.*	(16) Part.	(17) SO_2	(18) CO	(19) HC	(20) NO_2
E. SUBAREA TOTAL																			

*Employment

Fig. 5-4. Industrial Point and New Source Emissions - Subarea Summary, Table 3.4-4 from Ref. 13

5.4 MASTER GRIDDING

To this point, the allocations for each source category may have been done with different spatial resolutions. It is possible that the county emission pattern may be described as in Fig. 5-5 with a variety of source presentations. It is now necessary to coordinate all of these results onto a single master grid system that can be used for modeling and strategy analysis.

Choice of Coordinates There are a variety of rectilinear coordinate systems that can be used in developing a master grid. It is desirable, however, to use Universal Transverse Mercator (UTM) coordinates, which are universally available on U.S. Geological Survey maps. The UTM coordinates offer the widest generality and applicability. The only translation problem occurs when an analysis area lies between two UTM zones where the abscissas are not continuous. This is easily treated via careful bookkeeping.

Some states have local coordinate systems that may be considered. Uncertainty as to the reference points will make these systems difficult to use for anyone unfamiliar with the area.

Selection of Grids The master grids chosen should, in general, be square with variations in size depending on the resolution of the subcounty areas. The smallest grid square chosen should be 1 km x 1 km. Smaller grids would result in data that does not, in all probability, exist in the original data set. The largest grid square chosen should be 8 km x 8 km. Larger grids would cancel some of the subcounty resolution already achieved.

Reference 8 describes a procedure for using Bureau of the Census computer tapes and the EPA-developed CAASE program (Computer-Assisted Area Source Emissions) for developing a grid based on population density. The process involves the interaction of a series of five computer programs and some manual techniques. This is one way in which the grid configuration can be developed.

An alternative method of developing a grid system is to rely on a review of the available subcounty areas. The process starts with an overlay of the largest grid squares (e.g., the 8 km x 8 km grid) placed on the subcounty area map. The grids are then subdivided until the smallest chosen grid size is reached or until the subdivision grid contains primarily one subcounty area.

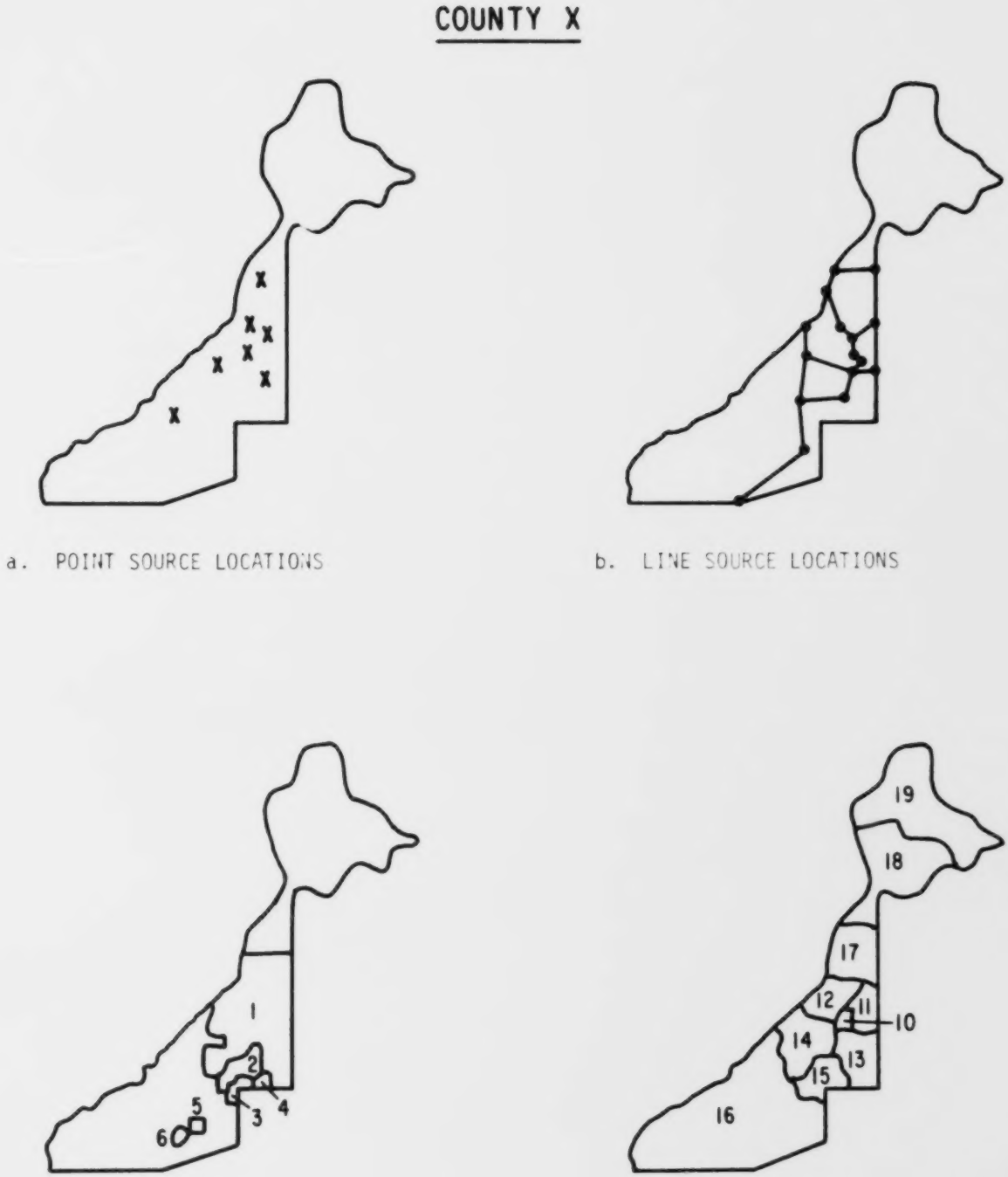

Fig. 5-5. Possible Displays of Spatial Emission Patterns

When the grid has been developed for one subcounty set (e.g., municipalities), it can then be laid over the other sets and be modified accordingly. This modification consists of further subdivisions to match the differing resolutions. Figure 5-6 gives the final grid system chosen for County X.

Subcounty Area Mapping Once the grid system has been chosen, it is necessary to map the subcounty areas into the master grid. This is done on an areal apportioning basis; that is, it is determined what fraction of a subcounty area (e.g., a census tract, municipality, etc.) is within the overlying grid square. All emissions from that area are then allocated to the master grid using this fraction. The computation is:

$$\text{Contribution of Subcounty Area i to total emissions in Grid j} = \text{Fraction of area of Subcounty Area i that lies in Grid j} \times \text{Total emissions in Subcounty Area i} \quad (5\text{-}1)$$

As an example, if 35% of the area of census tract 70 lies in grid square no. 5, then 35% of the emissions computed for census tract 70 will be assigned to grid 5. The area fractions may be determined using a planimeter or by using an "eyeball" estimation procedure.

Appendix H documents a computer code that can be used to map emissions from the subcounty areas onto the master grid once a complete set of area fractions is assembled.

Model Inputs With the development of the master grid network, it is now possible to use the emission data as input to a dispersion model. The master grids may be used as area sources and the previously identified point and line sources can be input directly. Alternatively, the point and line sources can be located in their appropriate master grids and the entire system modeled as a set of area sources.

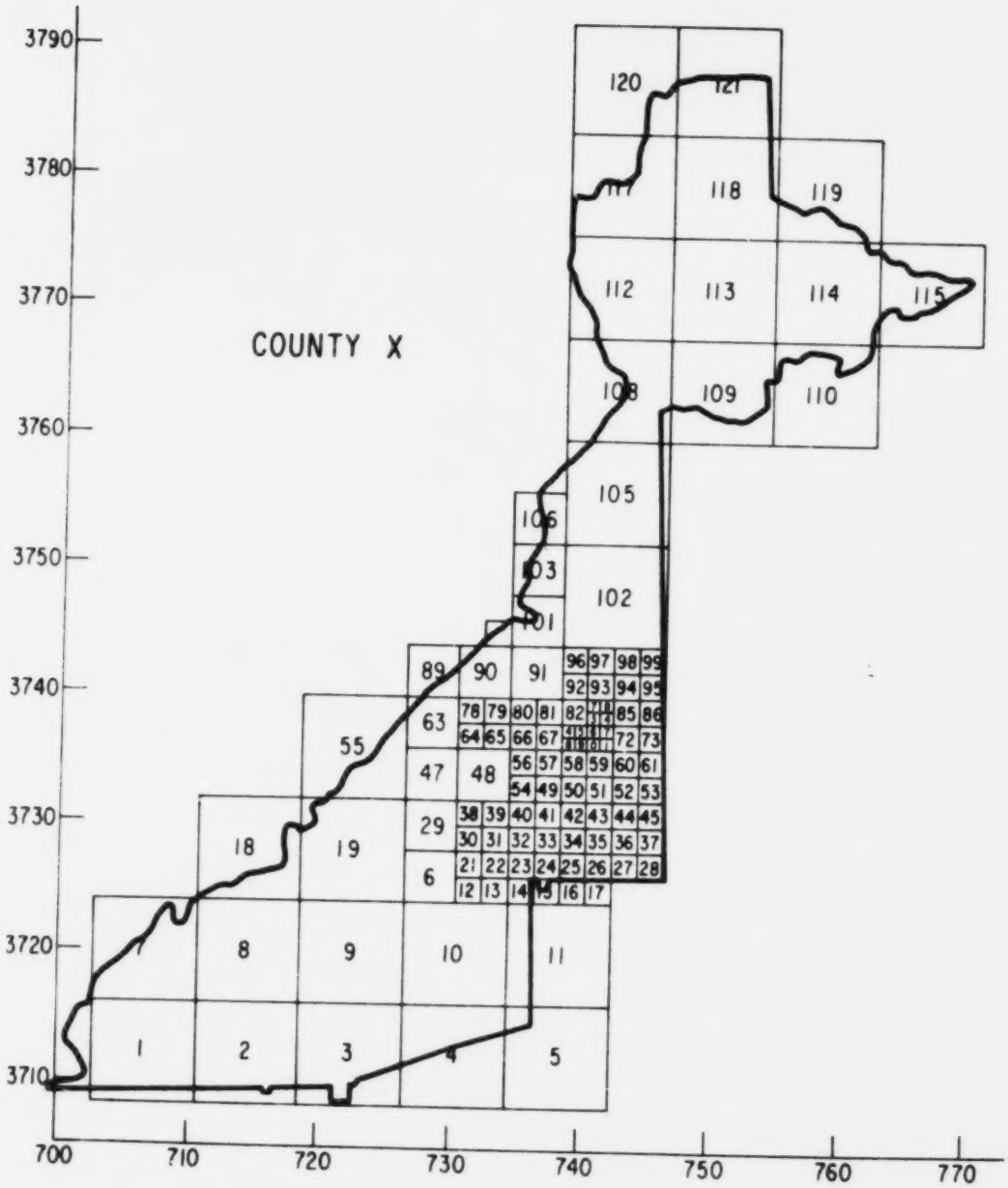

Fig. 5-6. Master Grid System for County X

PROBLEM 5-2

Using the grid map of a portion of County X given on Fig. 5-7, develop a grid system that matches the resolution of the indicated subcounty areas.

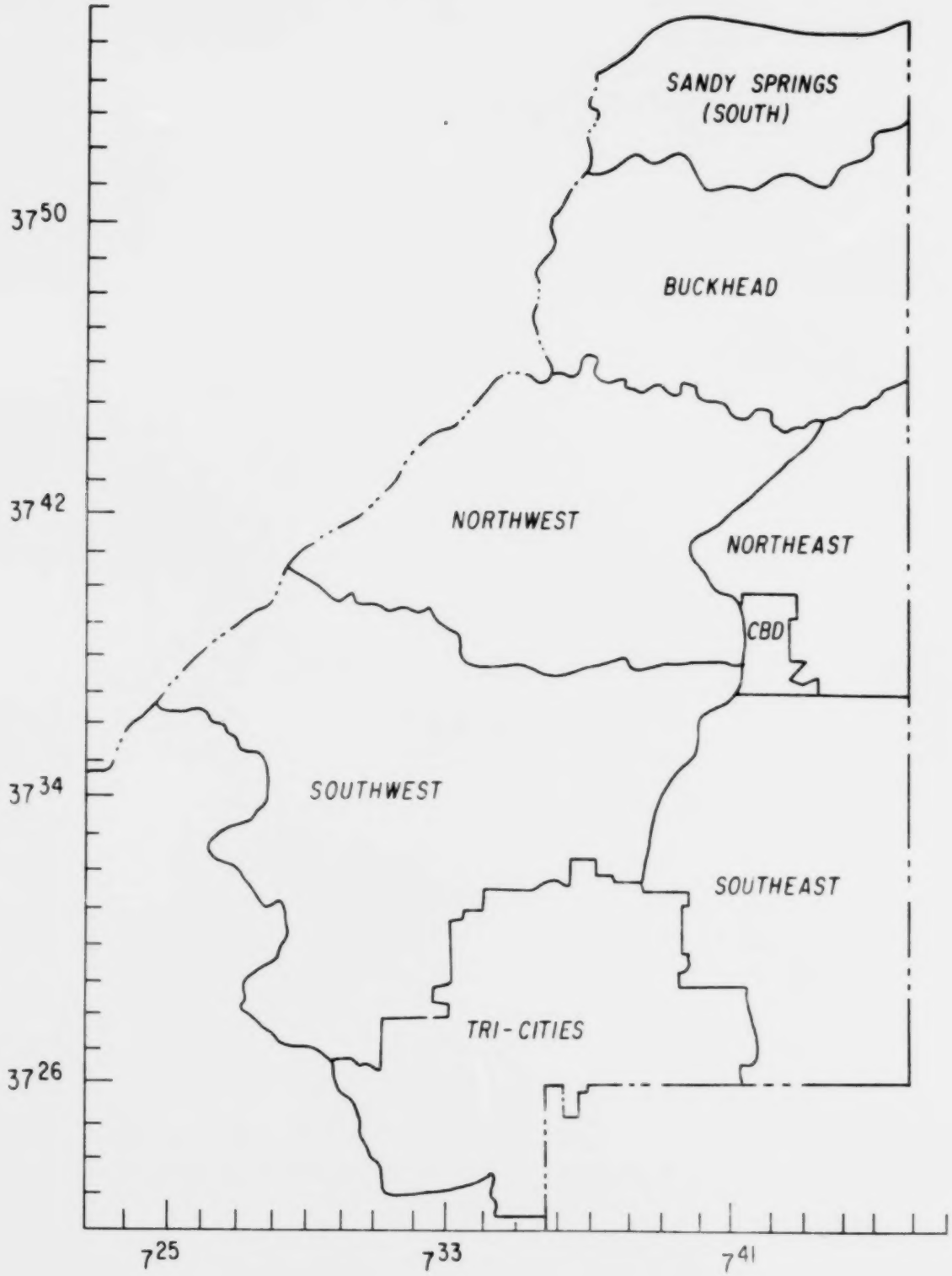

Fig. 5-7. Portion of County X for Gridding Problem 5-2

PROBLEM 5-3

Using the solution map of Problem 5-2, determine the area fractions for the Northwest Superdistrict into its overlaying grid squares. The total area of the district is known to be 77.0 sq km.

6. MODELING PROCEDURES

An atmospheric simulation model is used to convert the air pollutant emission data into ambient air pollutant concentration estimates. The model is an analytical tool that helps the air quality analyst determine the effectiveness of his control strategies. Like any tool, the model is useful only if the user understands its strengths and weaknesses and does not attempt to apply it beyond its capabilities. Perhaps the most widespread abuse of atmospheric simulation is to regard the model as a mystical "black box" that magically transforms emissions into air quality. This approach to modeling is most likely to lead to erroneous results and to an analysis that will not withstand technical challenge.

6.1 CHOICE OF MODEL

There are numerous simulation models available to the air quality analyst. These models vary widely in their data requirements, complexity, accuracy, and applicability. Reference 12 gives concise descriptions of some of the more widely used multi-source models (i.e., models that can be used to study the impact of many sources or source categories on air quality), and these are summarized on Table 6.1. The Rollback and Appendix J models rely on proportional reduction assumptions; that is, if emissions are reduced by a given amount, the concentrations will be reduced proportionately. Both are only useful for rough approximations of air quality impacts. The Miller-Holzworth model uses a dispersion equation that is integrated over an entire urban area. It is a step better than Rollback in that it can be used where there are no observed air quality data available. Both the annual and short-term versions of the Hanna-Gifford model use a simplified dispersion equation to compute the concentration over each area in which a receptor is located. The basic Hanna-Gifford model can be improved with the addition of either a point source or line source model to provide better spatial resolutions. The Air Quality Display Model (AQDM) and its companion, the Climatological Display Model (CDM) use a Gaussian-plume calculation to estimate specific source-receptor contributions on an annual average. These are the most widely used models in air quality analyses. The Sampled Chronological Input Model (SCIM) and the Real Time Air Quality Simulation Model (RAM) also use a Gaussian-plume calculation, but on an hourly basis. The APRAC-1A model is

used for mobile source emissions and is a line source formulation for use with highway links. The SAI model is a photochemical model that incorporates both dispersion and atmospheric chemical reactions.

Table 6.1. Multi-Source Atmospheric Dispersion Models

Model	Model Technique
1. Rollback	Proportional reduction
2. Appendix J	Proportional reduction of oxidant concentration to hydrocarbon emissions
3. Miller-Holzworth	Integration of Gaussian dispersion across an urban area
4. Hanna-Gifford	Simplified dispersion equation over an area
5. Hanna-Gifford with Point Source	Addition of specific point source calculations to basic Hanna-Gifford
6. Hanna-Gifford with HIWAY	Addition of line source calculations to basic Hanna-Gifford
7. Air Quality Display Model (AQDM) (also Climatological Display Model (CDM))	Gaussian plume concentration calculations for annual averages
8. Sampled Chronological Input Model (SCIM) (also Real Time Air Quality Simulation Model (RAM))	Gaussian plume concentration calculations for 1-hour averages
9. APRAC-1A	Line source calculations for highway and street links
10. SAI	Photochemical reaction and dispersion calculations

In addition to these multi-source models, there are a variety of single source models available that can be used to evaluate the impact of isolated point sources or to develop control measures applicable to only a few sources in an urban area. These models can be used to conduct microscale analyses to further clarify and amplify the macroscale results of the multi-source models. (This has been alluded to in the discussion of the Hanna-Gifford

Model.) Descriptions of the available models are given in References 10, 24, 34, and 35. Computerized models are also available.[36,37] The discussion of Reference 10 indicates how such models might be used to implement a new source review program to identify the impacts of large, new emission sources. An indirect source review program[9] can also make use of some of the microscale analysis techniques.

There are numerous other models available for use in an air quality analysis. Appendix A in Chapter 40, Part 51 of the Code of Federal Regulations, presents EPA's general position as to the appropriate and acceptable use of specific air quality simulation models. The EPA Regional Office should, however, be consulted to determine the acceptability of comparable models.

The choice of model is a function of many considerations including the following:

Pollutant	Ease of use
Averaging time	Availability
Data requirements	Reliability
Model output	Applicability to air quality analysis

Table 6.2, taken from Reference 12, evaluates each of these considerations for the ten most commonly used models. In some cases a model that specifies one averaging time can be used to estimate concentrations for other averaging times by using statistical techniques such as those described by Larsen[17] and Turner.[24]

Proposed regulations require that, at a minimum, AQDM or equivalent model be used for the air quality analysis of particulates and SO_2 with appropriate estimations made for short-term standards.[14] Proportional modeling will be acceptable for CO and NO_2, while Appendix J will be acceptable for oxidants. Table 6.3 gives the applicability of each model to an analysis of each of the NAAQS pollutants. Deviations from these general guidelines are possible with EPA Regional Office concurrence.

6.2 MODEL OUTPUTS

The output of the models varies considerably as indicated on Table 6.2. The Rollback, Appendix J, Miller-Holzworth, and basic Hanna-Gifford

Table 6-2. Summary of Simulation Model Characteristics

Model Name	Pollutant Specification	Averaging Time Specification	Emission Data	Meteorological Data	Concentration Estimates	Ease of Use	Availability	Reliability	Applicability to AQAS
Rollback	Any	Any	1	1	3	1	1	3	3
Appendix J	O_x	1 hr	1	1	3	1	1	3	3
Miller-Holzworth	SO_2,TSP	1 hr, Annual	1	3	3	1	1	1	3
Hanna-Gifford	SO_2,TSP CO	Annual	1	2	3	1	1	1	3
Hanna-Gifford	SO_2,TSP	1-24 hr	2	5	2	2	1	1	2
w/PS[a] model	SO_2,TSP	1-24 hr	3	5	1	2	2	1	1
w/HIWAY	CO	1-24 hr	3	5	1	2	2	1	1
AQDM, CDM	SO_2,TSP	Annual	3	4	1	3	2	1	1
SCDM,[b] RAM[b]	SO_2,TSP	1-24 hr	3	5	1	3	3	2	1
APRAC-1A	CO	1-24 hr	3	5	1	3	2	2	1
SAI[b]	CO,NO_2,O_x	1-10 hr	2	5	2	3	3	2	2

[a]Point Source

[b]These models are currently in a developmental and debugging phase; they are not available for general distribution as computer programs.

Key to Table 6.2

A. Pollutant Specification
   - Any pollutant
   - Specific Pollutants (SO_2, TSP, CO, O_x, NO_2)

B. Averaging-time Specification
   - Any averaging time
   - Annual Average
   - 1 to 24 hour Average

C. Emission Data
   1. Area-wide Emissions Total
   2. Total emission distributed as finite area sources
   3. Detailed point, line, and area sources

D. Meteorological Data
   1. None
   2. Average wind speed
   3. Average wind speed and mixing height
   4. Frequency distribution of wind direction, wind speed, stability, and mixing height
   5. Hourly variations of wind direction, wind speed, stability, and mixing height

E. Concentration Estimates
   1. Estimates at any specified point
   2. One estimate for each area source grid
   3. One estimate applicable to entire AQMA

F. Ease of Use
   1. Slide-rule
   2. Small computer effort
   3. Major computer effort

G. Availability
   1. Open literature
   2. National Technical Information Service
   3. EPA, upon request

H. Reliability
   1. Can be verified and calibrated
   2. Verification is incomplete, possibility of calibration is uncertain
   3. Questionable; acceptable for crude estimates only

I. Applicability to AQAS
   1. Can distinguish between specific source and land use type
   2. Can distinguish between land use types only
   3. Considers no distinction between sources or land uses

Table 6-3. Models Applicable to Specific Pollutants and Averaging Times

Pollutant and Averaging Times	Preferred Model	Alternative Models	
		Model	Condition of Applicability
SO_2, TSP Annual Average	1. AQDM	1. Hanna-Gifford	Inadequate computer facilities
	2. CDM	2. Rollback	Complex topography and/or Meteorology
		3. More sophisticated model	Complex topography and/or meteorology
		4. Miller-Holzworth	No circumstances currently envisioned permit its use
SO_2, TSP 24-hr and 3-hr Averages	1. AQDM[a]	1. SCIM,[b] RAM	Availability
	2. CDM[a]	2. Hanna-Gifford w/point source[b]	Inadequate computer facilities
	3. Single-source models	3. Rollback	Complex topography and/or meteorology
		4. More sophisticated model	Complex topography and/or meteorology
		5. Miller-Holzworth	No circumstances currently envisioned permit its use
CO 1-hr and 8-hr Averages	1. ARAC-1A	Rollback	Unavailability of other models
	2. Hanna-Gifford w/ HIWAY		
Oxidants 1-hr Average	1. SAI	Rollback	Demonstration that Appendix J is not applicable to region
	2. Appendix J		
NO_2 Annual Average	1. Rollback		
	2. Single-source models[c]		

[a]Statistical conversion of averaging times required.

[b]Repetitious application of model to each hour under consideration is required for averaging times longer than 1-hr.

[c]Usable only when atmospheric chemical reactions are not significant over the impact area.

models result in a single estimate of pollutant concentration applicable over the entire region under study. These models are, therefore, applied to the expected worst receptor in the region. The short-term Hanna-Gifford model can generate a concentration estimate over an area source grid. It can also give concentrations at any point when coupled with a point source model or with the HIWAY model. The SAI photochemical model calculates concentrations over an area source grid. All the other models can compute concentrations at any specified receptor point. A sample printout of the AQDM model is given on Fig. 6-1. The receptor coordinates and the computed concentrations are shown.

Another useful form of output for those models that can compute concentrations at any point is the isopleth or line of constant concentration. If the computations are made at a large enough number of receptor points, then the isopleths are easily drawn by interpolating between adjacent points. A standardized computer program, SYMAP, is available,[38] which uses a computer line printer to draw the isopleths. Figure 6-2 is a sample output of the SYMAP program, which has been coupled to the AQDM model. The printer draws a symbol to represent the concentration level and also prints the computed concentration at each selected receptor point. The concentration intervals can be determined manually or automatically. The use of isopleths is an extremely valuable tool in visualizing the general air quality situation and identifying "hot spots," although its use is not critical to the air quality analysis.

In determining the impact of various sources on air quality at a given location, it is necessary to develop a culpability list; that is, a list of the contributions of each source to the calculated concentration at a given receptor. Since all of the models make use of the principle of superposition in that the concentration is calculated as the sum of the emissions dispersed from each individual source, it is conceptually straightforward to develop the list. In practice, without computer assistance the task would be extremely laborious for all but a very small number of sources. The AQDM model has a routine incorporated into it that prepares such a list with no additional burden on the user. Figure 6-3 demonstrates the output of this routine. This information is extremely useful in control strategy development and analysis. If a model is being used that does not have such a routine built-in, it is highly recommended that the effort be expended to develop and incorporate one.

RECEPTOR CONCENTRATION DATA

RECEPTOR NUMBER	RECEPTOR LOCATION (KILOMETERS) HORIZ	VERT	EXPECTED ARITHMETIC MEAN (MICROGRAMS/CU. METER) SO2	PARTICULATES
121	73[illegible]	[illegible]	0.	60.
122	73[illegible]	[illegible]	0.	61.
123	73[illegible]	[illegible]	0.	57.
124	73[illegible]	[illegible]	0.	55.
125	73[illegible]	3770.0	0.	53.
126	73[illegible]	[illegible]	0.	51.
127	73[illegible]	[illegible]	0.	49.
128	73[illegible]	[illegible]	0.	48.
129	[illegible]	[illegible]	0.	53.
130	[illegible]	[illegible]	0.	55.
131	[illegible]	[illegible]	0.	58.
132	[illegible]	[illegible]	0.	66.
133	[illegible]	[illegible]	0.	78.
134	[illegible]	[illegible]	0.	75.
135	[illegible]	[illegible]	0.	77.
136	[illegible]	[illegible]	0.	69.
137	[illegible]	[illegible]	0.	62.
138	[illegible]	[illegible]	0.	7[illegible].
139	[illegible]	[illegible]	0.	60.
140	[illegible]	[illegible]	0.	55.
141	[illegible]	[illegible]	0.	55.
142	74[illegible]	[illegible]	0.	52.
143	[illegible]	[illegible]	0.	50.
144	[illegible]	[illegible]	0.	48.
145	[illegible]	[illegible]	0.	54.
146	[illegible]	[illegible]	0.	57.
147	[illegible]	[illegible]	0.	62.
148	[illegible]	[illegible]	0.	[illegible]
149	[illegible]	[illegible]	0.	[illegible]
150	[illegible]	[illegible]	0.	76.
151	[illegible]	[illegible]	0.	61.
152	[illegible]	[illegible]	0.	72.
153	[illegible]	[illegible]	0.	80.
154	[illegible]	[illegible]	0.	95.
155	[illegible]	[illegible]	0.	67.
156	[illegible]	[illegible]	0.	63.
157	[illegible]	[illegible]	0.	57.
158	[illegible]	[illegible]	0.	51.
159	[illegible]	[illegible]	0.	50.
160	[illegible]	[illegible]	0.	48.

Reproduced from best available copy.

Fig. 6-1. Sample AQDM Output

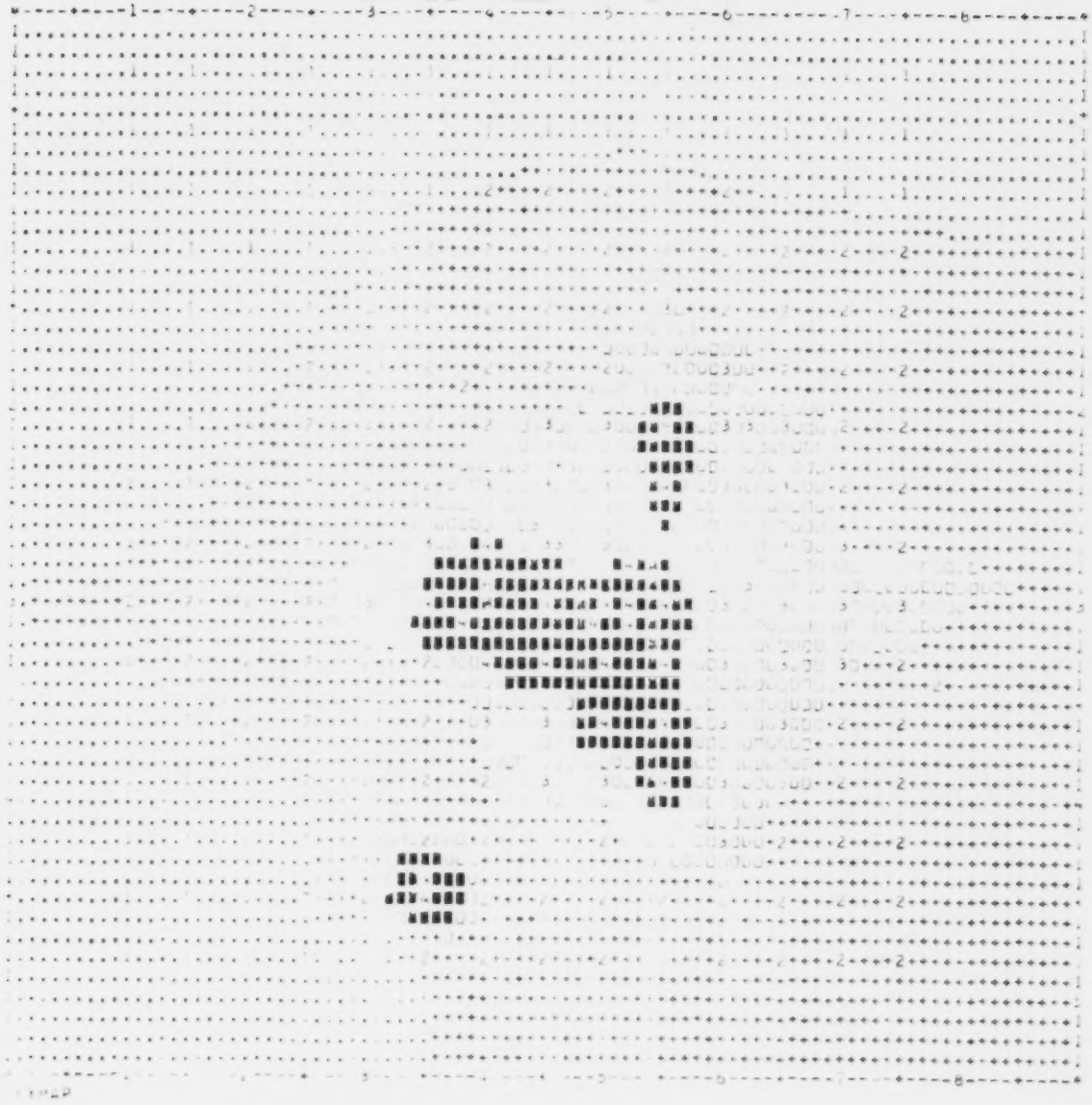

Fig. 6-2. Sample SYMAP Output

SOURCE [illegible] RECEPTORS

ANNUAL [illegible] PARTICULATES

[illegible] PER CUBIC METER

SOURCE	RECEPTOR 131	RECEPTOR 1[illegible]	RECEPTOR 132	RECEPTOR [illegible]11	RECEPTOR 2[illegible]
4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] %
	[illegible]	[illegible]	[illegible]	[illegible]	0.0015
4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].24 %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.02 %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.01 %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	0.0[illegible] %	[illegible] %	[illegible] %	[illegible].01 %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
51	[illegible]	3.01 %	[illegible] %	[illegible].22 %	[illegible].50 %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.27 %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] %	[illegible] %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5[illegible]	[illegible]	[illegible]	[illegible]	[illegible] %	[illegible] %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
55	[illegible]	[illegible]	[illegible]	[illegible] %	[illegible].72 %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5[illegible]	[illegible]	[illegible]	[illegible]	[illegible] %	[illegible].56 %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible] %	[illegible]	[illegible] %	2.27 %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5[illegible]	[illegible]	[illegible]	[illegible] %	[illegible]	[illegible] %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5[illegible]	[illegible] %	[illegible]	[illegible]	[illegible] %	[illegible] %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible] %	[illegible] %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6[illegible]	[illegible]	[illegible]	[illegible]	[illegible] %	[illegible] %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6[illegible]	[illegible]	[illegible]	[illegible]	[illegible] %	[illegible] %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
6[illegible]	[illegible] %	[illegible]	[illegible] %	[illegible] %	[illegible] %
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fig. 6-3. Sample AQDM Culpability List

6.3 MODEL VALIDATION AND CALIBRATION

6.3.1 Validation Procedures

As with all analytical tools, air quality simulation models are subject to errors that cause the computed concentrations to differ from observed values. The errors are of two basic types:

Errors in predicting variations in concentrations, and
Errors in predicting absolute levels.

The first type are systematic errors that indicate that the model is not accurately accounting for variations in emissions or dispersion. The second type of error indicates that the model is accounting for variations properly but the computed concentration is in error by some across-the-board quantity. This is most frequently explained by a background level that is not accounted for and is the least serious of the two errors.

There are numerous statistical tests that can be used to evaluate how well the calculated values compare to the observed. These include skill scores, contingency tables, comparison of time series and spatial variations, and correlation analyses. The latter, illustrated on Fig. 6-4, is the easiest to use and is incorporated into the AQDM model. It uses a graph of observed versus calculated values of concentration either at one receptor location (for several meteorological or emission conditions) or at a number of locations for a fixed set of conditions.

A least-square regression line of observed concentration values on the calculated values is then obtained. To determine the validity of using the model to calculate air quality levels, the coefficient of correlation, a measure of data-scatter about the regression line, is calculated and compared with the maximum theoretical value that could arise due to chance. The maximum theoretical value for a 5% confidence level (that is, there are fewer than 5 chances in 100 that a coefficient of correlation as high as this value would arise due to random sampling variation) is used as the criterion for acceptable validation in AQDM. A poor correlation coefficient warns the user that the input data and the model assumptions must be reviewed.

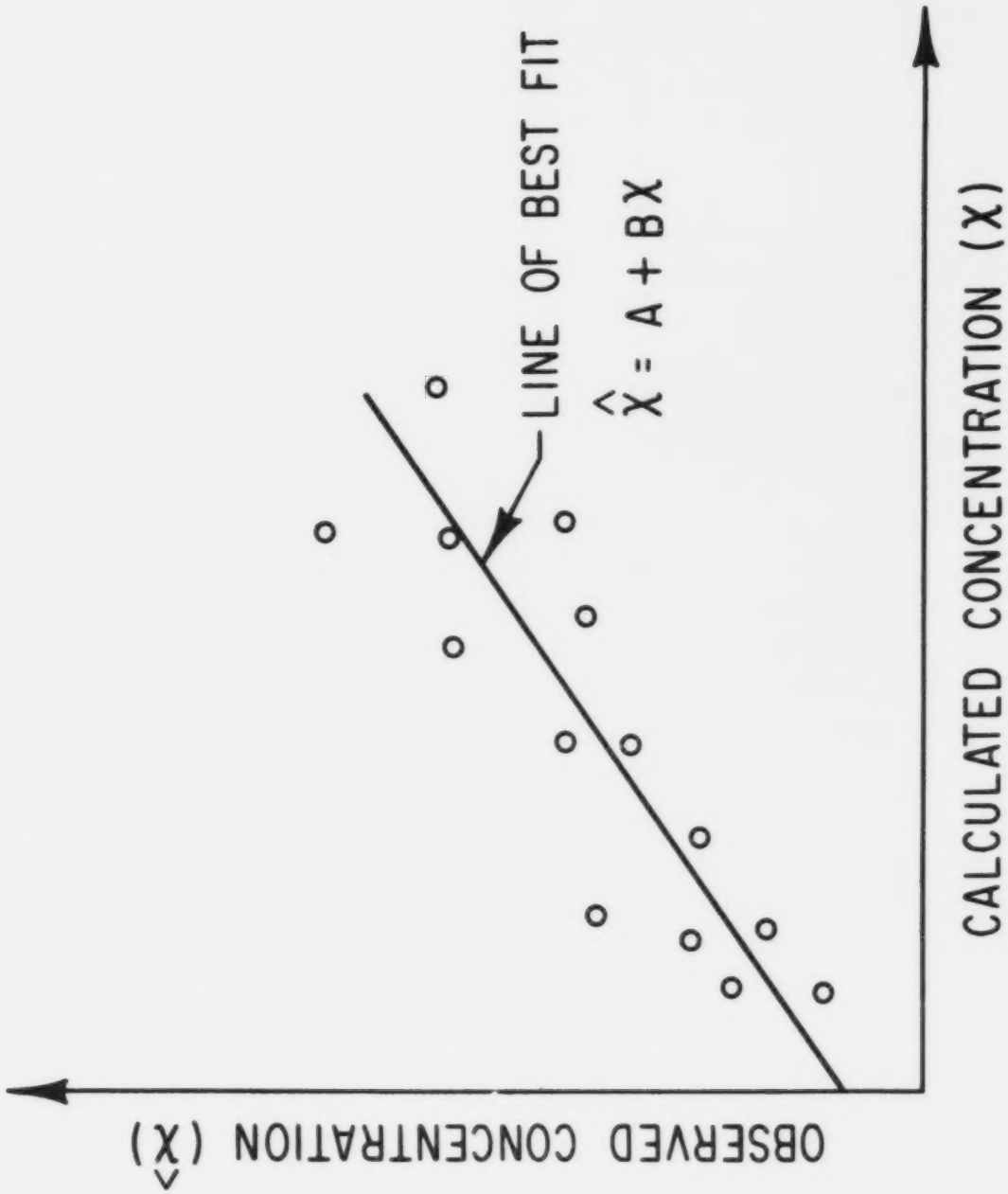

Fig. 6-4. Regression Analysis for Model Validation

6.3.2 Sources of Errors

The most frequently occurring reasons for a poor correlation between computed and observed concentrations are:

Inadequate emission inventory,
Unrepresentative air quality data,
Complex topography and/or meteorology,
Incomplete description of source variations, and
Unaccounted-for atmospheric processes.

By the nature of how emission inventories are developed, there is substantial room for error. This is especially true when the lower levels of emission estimation and spatial allocation are used. Some of the more glaring errors (e.g., the excessive domination of a single source) are correctable by further investigation of specific sources. The more subtle errors may elude a quick solution and may require substantial reinvestigation to identify the problems.

The unrepresentativeness of the observed data against which the calculations are compared is another source of a poor correlation. Data collected in an area dominated by a single source is often not suitable for comparison to the predicted values obtained from some multi-source models. Likewise, data collected from areas influenced by unusual emission patterns or terrain features make for poor validation points. These problems are relatively easy to compensate for by reviewing the locations of all the monitors and screening out unacceptable model validation data. References 11 and 19 give some guidelines on determining the representativeness of various monitor locations.

Only a few specialized models are adequate for use in complex terrain (e.g., mountain or valley locations) or for unusual meteorology (e.g., lake or ocean breeze circulation). Attempts to use other models in these circumstances will lead to erroneous results and misleading conclusions. Advice from EPA Regional Offices and/or headquarters is available to determine the suitability of various models.

Errors in calculated concentrations occur when the model is not capable of representing variations in the emission patterns of major sources.

If, for example, space heating emissions are significant, then the model must be able to distinguish between summer and winter emission patterns. Problems of this type can be identified by reviewing the culpability list to determine if the major sources are adequately treated in the simulation.

Atmospheric processes such as photochemical reactions, scavenging, and settling have a dramatic effect on concentrations. Of the models listed on Table 6.1, only the SAI model takes account of photochemistry. The state of the art of this type of model is still developmental and widespread applicability of these models has yet to be demonstrated. The removal of pollutants by scavenging (e.g., by washout, ground absorbtion, etc.) has been treated in some models by incorporating a half-life term in the dispersion equations. This term results in a steady reduction in concentrations in addition to the dispersion effects. Gravitational settling of particulates reduces concentrations in the same fashion as scavenging. The larger particulates (> 30 μm) tend to settle relatively quickly and hence should not be part of the observed concentrations. The emission inventory may be adjusted to reflect this situation by using emission factors representing source particulate size distribution. Sources for which this type of adjustment is most applicable are the industrial process sources (especially things like stone quarrying, rock crushing, etc.) and some fugitive dust sources (e.g., unpaved roads, agricultural tilling, etc.). Appendix F gives some further expansion of this.

6.3.3 Model Calibration

Once the dispersion model estimates have been validated or determined to be acceptable, the model may be calibrated. The calibration should account for systematic errors in the estimates. If the coefficient of correlation (calculated in AQDM, for example) is greater than the theoretical value for a 5% confidence level, the regression line is used to calibrate the calculated values. The slope of the regression line is used to adjust systematic errors in predicting variations in concentrations, and the intercept adjusts the prediction of absolute levels by accounting for missing input background concentration values.

Figure 6-5 gives the correlation analysis for County X using the baseline inventory and air quality data. The calculation shows the 5% confidence level to correspond to a correlation coefficient of 0.532. The

REGRESSION PARAMETERS FOR CALCULATED (X-AXIS) VS. OBSERVED (Y-AXIS) CONCENTRATIONS

POLLUTANT	Y-INTERCEPT (MICROGRAMS/CU. METER)	SLOPE	REGRESSION COEFFICIENTS	
			COMPUTED	5% CONE. LEVEL
PARTICULATES	31.2	0.1992	0.629	0.532

CORRELATION DATA

PARTICULATE MONITORING STATION	RECEPTOR LOCATION (KILOMETERS)		PARTICULATE CONCENTRATION (MICROGRAMS/CU. METER)	
	HORIZONTAL	VERTICAL	OBSERVED	CALCULATED
1	742.2	3737.9	58.	132.
2	744.1	3730.2	50.	111.
3	742.3	3744.0	50.	120.
4	741.9	3739.6	59.	148.
5	728.5	3737.9	45.	92.
6	734.1	3743.0	61.	120.
7	743.8	3736.5	61.	129.
8	738.7	3738.7	53.	111.
9	735.8	3745.2	58.	103.
10	751.9	3741.6	49.	94.
11	767.9	3734.2	49.	80.
12	751.6	3754.6	63.	147.
13	724.5	3716.2	40.	107.
14	727.8	3758.9	55.	86.

Fig. 6-5. AQDM Regression Analysis for County X

computed correlation coefficient is 0.629, thus indicating an acceptable validation. The y-intercept of 31.2 μg/m³ is within acceptable levels for background particulate levels, but the small slope indicates the model to be relatively insensitive to changes in emission patterns. The calibration equation is the following:

$$\chi_{observed} = 0.199\ \chi_{calculated} + 31.2 \qquad (6\text{-}1)$$

This equation is then used to correct all future concentration calculations.

6.3.4 Background Concentrations

Some pollutants occur naturally in the atmosphere independently of any human activity. Since simulation models rely on a description of all emission sources, they are likely to underpredict the absolute concentration by an amount equal to this background level and must be corrected. In another context, background concentrations can be interpreted as the material transported into the region of study from external sources, the nature of which is unknown. In both cases, the background level is added to all computed concentrations.

Background levels may be determined from air quality monitors upwind of major source activities. The levels can be expected to lie in the ranges given in Table 6-4.

Table 6-4. Range of Background Concentrations

Pollutant	Concentration (μg/m³)
Particulates	30-40
SO_2	∿ 0
CO	∿ 0
NO_2	∿ 0
Oxidants	∿ 0[a]

[a]The Appendix J model is based on a zero background concentration of hydrocarbons and oxidants.

6.4 COUNTY X MODELING RESULTS

The Air Quality Display Model (AQDM) was used to perform the air quality analysis for County X. Figures 6-6 to 6-8 illustrate the particulate air quality computed for 1975, 1980, and 1985 as plotted from the SYMAP routine. Table 6.5 is a composite of the computed air quality from the AQDM output tables. In making these computations it was assumed that no new control programs were in force, only existing regulations and federal New Source Performance Standards were assumed to be in effect, and source compliance data, where available, were used to determine actual emissions.

It is evident from Fig. 6-6 that there are several areas in the county exceeding the primary NAAQS for particulates of 75 $\mu g/m^3$ and that there are much wider-spread violations of the secondary standard of 60 $\mu g/m^3$. By 1980, Fig. 6-7, growth and development has caused significant increases in the area in excess of both the primary and secondary standards. In the period between 1980 and 1985 (Fig. 6-8), the growth in NAAQS violation areas has slowed markedly to a point of little increase. This is the result of the imposition of New Source Performance Standards that arrest the growth in emissions. This fact is evidenced by the change in county emissions as illustrated on Table 4-1.

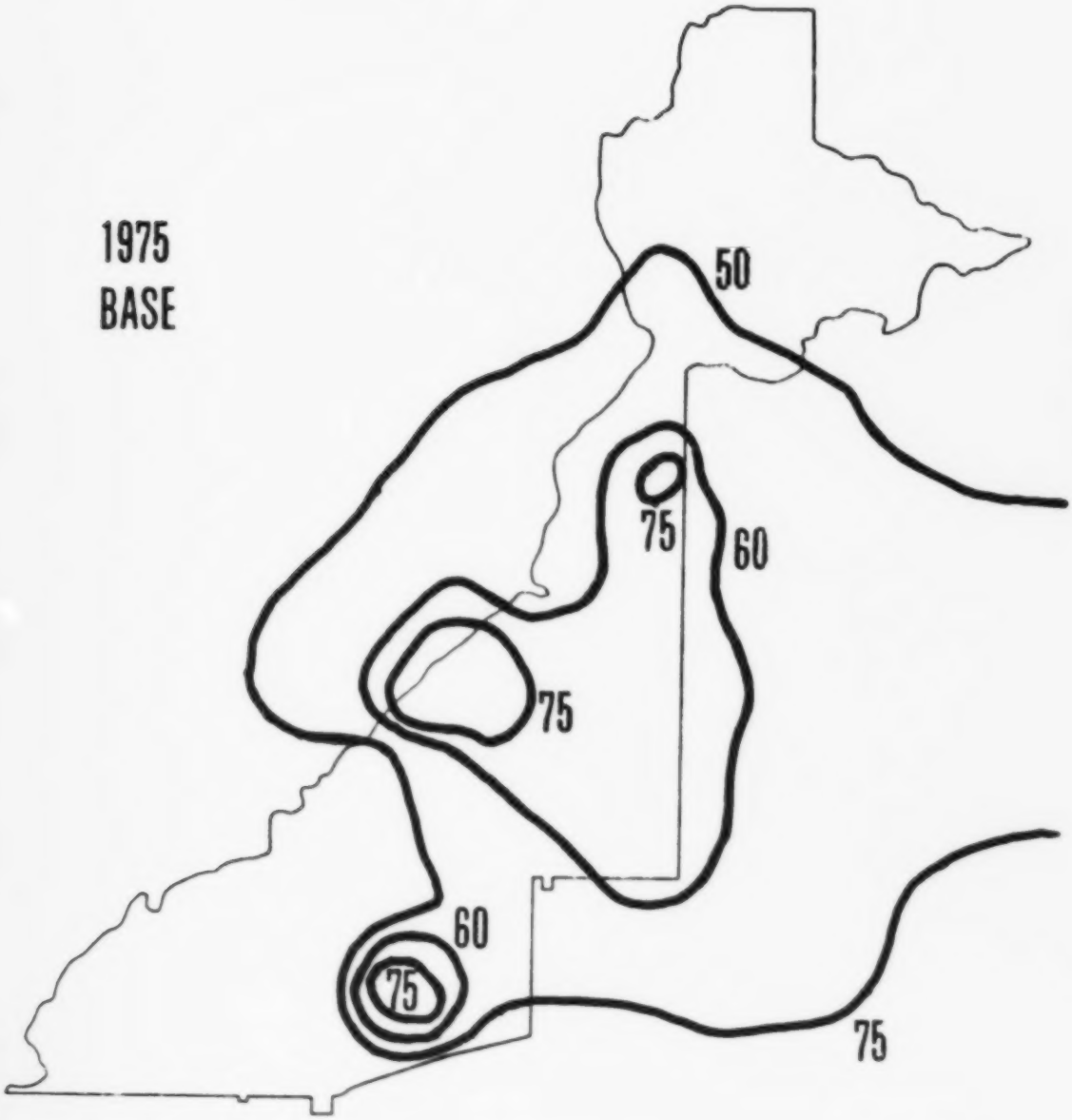

Fig. 6-6. County X Particulate Air Quality in 1975 Under Base Conditions

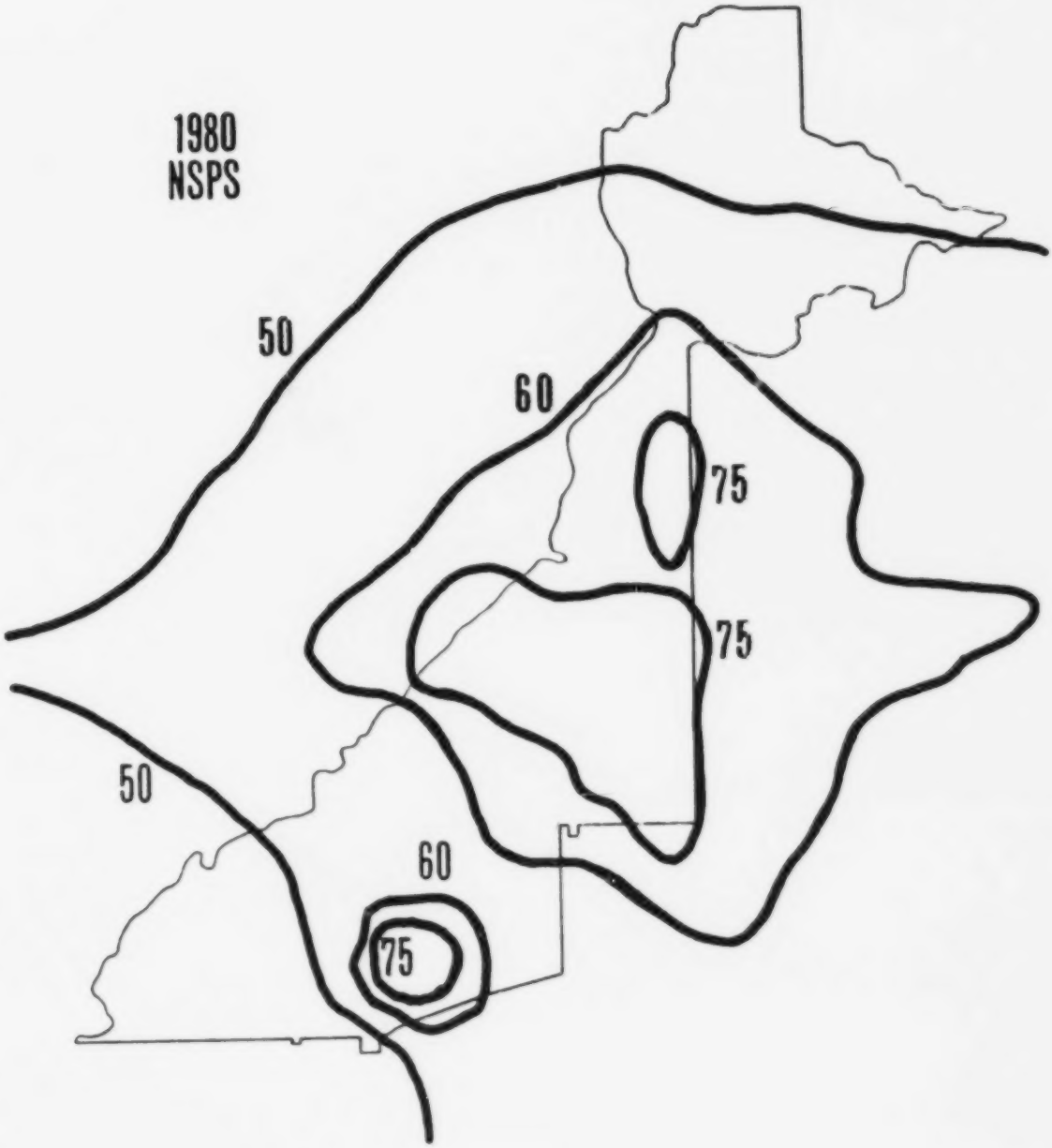

Fig. 6-7. County X Particulate Air Quality in 1980 Under NSPS Only

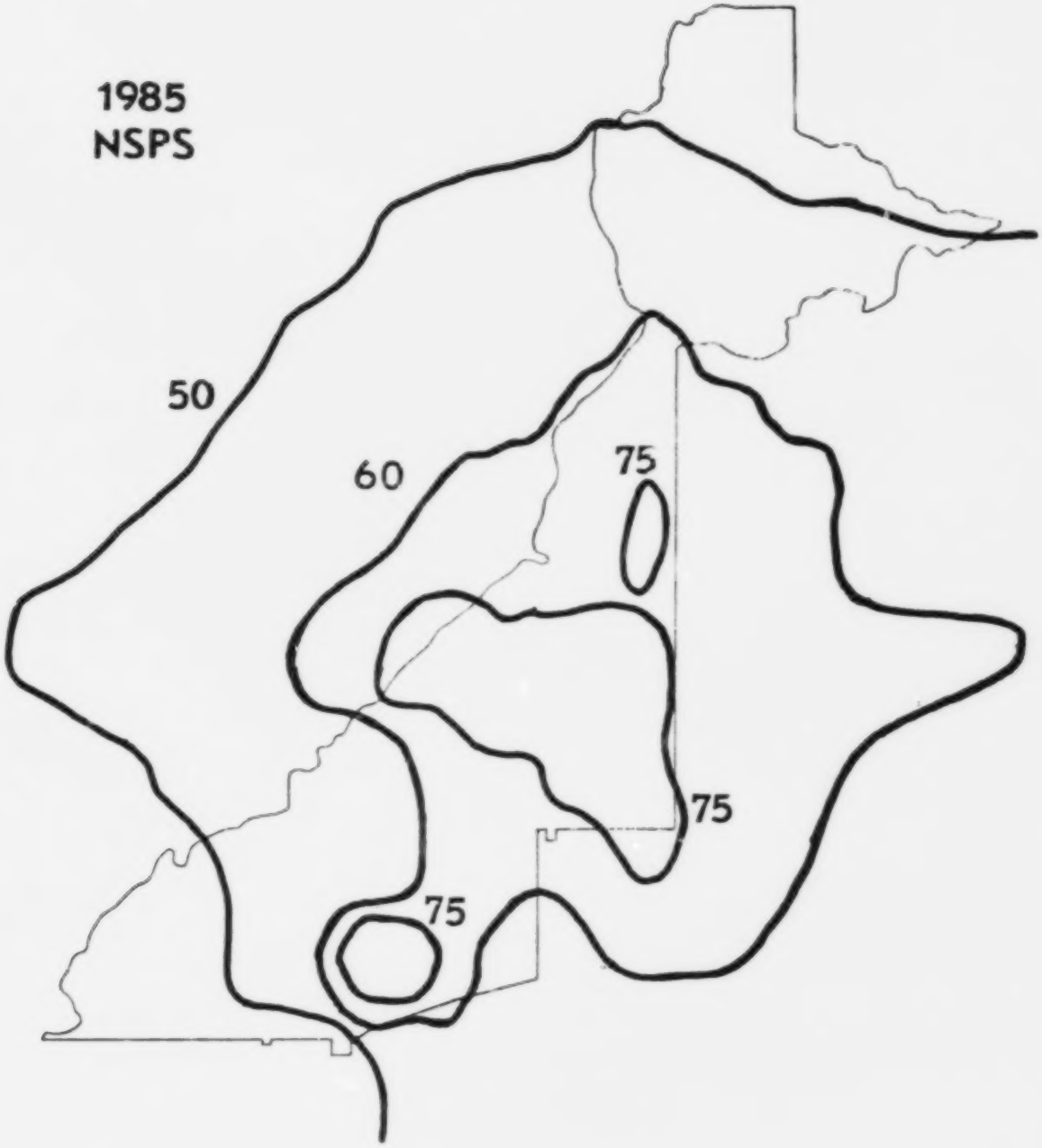

Fig. 6-8. County X Particulate Air Quality in 1985 Under NSPS Only

Table 6-5. Composite of Computed Air Quality for County X from AQDM

RECEPTOR NUMBER	RECEPTOR LOCATION		EXPECTED ARITHMETIC MEAN (MICROGRAMS/CU. METER) 1975	1980	1985
	X	Y	PARTICULATES	PARTICULATES	PARTICULATES
1	[illegible]	[illegible]	42.	44.	45.
2	[illegible]	[illegible]	43.	45.	46.
3	[illegible]	[illegible]	43.	47.	47.
4	[illegible]	[illegible]	44.	47.	47.
5	[illegible]	[illegible]	44.	49.	49.
6	[illegible]	[illegible]	45.	50.	50.
7	[illegible]	[illegible]	46.	50.	50.
8	[illegible]	[illegible]	46.	50.	50.
9	[illegible]	[illegible]	45.	48.	49.
10	[illegible]	[illegible]	44.	48.	48.
11	[illegible]	[illegible]	44.	47.	47.
12	[illegible]	[illegible]	43.	46.	46.
13	[illegible]	[illegible]	43.	46.	46.
14	[illegible]	[illegible]	42.	45.	45.
15	[illegible]	[illegible]	42.	45.	45.
16	[illegible]	[illegible]	42.	44.	44.
17	[illegible]	[illegible]	43.	45.	45.
18	[illegible]	[illegible]	43.	46.	47.
19	[illegible]	[illegible]	44.	47.	48.
20	[illegible]	[illegible]	44.	48.	48.
21	[illegible]	[illegible]	45.	49.	49.
22	[illegible]	[illegible]	46.	51.	51.
23	[illegible]	[illegible]	47.	52.	52.
24	[illegible]	[illegible]	47.	51.	51.
25	[illegible]	[illegible]	46.	50.	50.
26	[illegible]	[illegible]	45.	49.	49.
27	[illegible]	[illegible]	46.	48.	48.
28	[illegible]	[illegible]	44.	47.	47.
29	[illegible]	[illegible]	43.	46.	46.
30	[illegible]	[illegible]	43.	46.	46.
31	[illegible]	[illegible]	42.	45.	45.
32	[illegible]	[illegible]	42.	44.	44.
33	[illegible]	[illegible]	43.	47.	48.
34	[illegible]	[illegible]	44.	48.	49.
35	[illegible]	[illegible]	45.	49.	49.
36	[illegible]	[illegible]	46.	50.	50.
37	[illegible]	[illegible]	46.	50.	51.
38	[illegible]	[illegible]	48.	53.	53.
39	[illegible]	[illegible]	49.	55.	55.
40	[illegible]	[illegible]	48.	53.	53.

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Table 6-5. (Cont'd)

RECEPTOR NUMBER	[illegible]	[illegible]	EXPECTED ARITHMETIC MEAN (MICROGRAMS/CU. METER) 1975 PARTICULATES	1980 PARTICULATES	1985 PARTICULATES
44	[illegible]	[illegible]	47.	51.	51.
45	[illegible]	[illegible]	46.	50.	50.
46	[illegible]	[illegible]	45.	49.	49.
47	[illegible]	[illegible]	45.	48.	48.
48	[illegible]	[illegible]	44.	47.	47.
49	[illegible]	[illegible]	43.	46.	47.
50	[illegible]	[illegible]	43.	45.	46.
51	[illegible]	[illegible]	42.	45.	45.
52	[illegible]	[illegible]	45.	49.	50.
53	[illegible]	[illegible]	46.	50.	52.
54	[illegible]	[illegible]	45.	50.	50.
55	[illegible]	[illegible]	46.	51.	51.
56	[illegible]	[illegible]	47.	52.	52.
57	[illegible]	[illegible]	49.	56.	56.
58	[illegible]	[illegible]	51.	58.	58.
59	[illegible]	[illegible]	49.	55.	55.
60	[illegible]	[illegible]	48.	53.	53.
61	[illegible]	[illegible]	47.	52.	52.
62	[illegible]	[illegible]	46.	50.	51.
63	[illegible]	[illegible]	45.	49.	50.
64	[illegible]	[illegible]	45.	48.	49.
65	[illegible]	[illegible]	44.	47.	47.
66	[illegible]	[illegible]	43.	46.	46.
67	[illegible]	[illegible]	42.	45.	45.
68	[illegible]	[illegible]	44.	43.	44.
69	[illegible]	[illegible]	50.	55.	57.
70	[illegible]	[illegible]	46.	54.	52.
71	[illegible]	[illegible]	47.	55.	52.
72	[illegible]	[illegible]	47.	52.	53.
73	[illegible]	[illegible]	57.	57.	57.
74	[illegible]	[illegible]	55.	65.	64.
75	[illegible]	[illegible]	52.	58.	58.
76	[illegible]	[illegible]	49.	55.	55.
77	[illegible]	[illegible]	44.	54.	54.
78	[illegible]	[illegible]	47.	52.	52.
79	[illegible]	[illegible]	46.	51.	51.
80	[illegible]	[illegible]	45.	50.	50.
81	[illegible]	[illegible]	49.	53.	58.
82	[illegible]	[illegible]	44.	47.	47.
83	[illegible]	[illegible]	43.	50.	50.

Table 6-5. (Cont'd)

RECEPTOR NUMBER	[illegible]	[illegible]	EXPECTED ARITHMETIC MEAN (MICROGRAMS/CU. METER) 1975 PARTICULATES	1980 PARTICULATES	1985 PARTICULATES
[illegible]	[illegible]	[illegible]	83.	51.	51.
[illegible]	[illegible]	[illegible]	74.	104.	125.
[illegible]	[illegible]	[illegible]	51.	58.	59.
[illegible]	[illegible]	[illegible]	57.	54.	55.
[illegible]	[illegible]	[illegible]	47.	54.	55.
[illegible]	[illegible]	[illegible]	52.	59.	60.
[illegible]	[illegible]	[illegible]	63.	77.	76.
[illegible]	[illegible]	[illegible]	55.	63.	63.
[illegible]	[illegible]	[illegible]	51.	56.	58.
[illegible]	[illegible]	[illegible]	55.	56.	57.
[illegible]	[illegible]	[illegible]	47.	54.	54.
[illegible]	[illegible]	[illegible]	46.	53.	53.
[illegible]	[illegible]	[illegible]	50.	51.	51.
[illegible]	[illegible]	[illegible]	45.	49.	50.
[illegible]	[illegible]	[illegible]	44.	48.	45.
[illegible]	[illegible]	[illegible]	53.	57.	57.
[illegible]	[illegible]	[illegible]	49.	55.	57.
[illegible]	[illegible]	[illegible]	53.	59.	62.
[illegible]	[illegible]	[illegible]	52.	58.	61.
[illegible]	[illegible]	[illegible]	54.	59.	63.
[illegible]	[illegible]	[illegible]	54.	62.	63.
[illegible]	[illegible]	[illegible]	62.	76.	76.
[illegible]	[illegible]	[illegible]	29.	55.	75.
[illegible]	[illegible]	[illegible]	67.	[illegible]	81.
[illegible]	[illegible]	[illegible]	55.	62.	62.
[illegible]	[illegible]	[illegible]	54.	62.	60.
[illegible]	[illegible]	[illegible]	50.	56.	57.
[illegible]	[illegible]	[illegible]	51.	53.	59.
[illegible]	[illegible]	[illegible]	47.	52.	53.
[illegible]	[illegible]	[illegible]	45.	50.	51.
[illegible]	[illegible]	[illegible]	53.	57.	53.
[illegible]	[illegible]	[illegible]	44.	47.	48.
[illegible]	[illegible]	[illegible]	48.	53.	55.
[illegible]	[illegible]	[illegible]	50.	55.	58.
[illegible]	[illegible]	[illegible]	51.	57.	59.
[illegible]	[illegible]	[illegible]	53.	64.	65.
[illegible]	[illegible]	[illegible]	62.	72.	72.
[illegible]	[illegible]	[illegible]	69.	87.	87.
[illegible]	[illegible]	[illegible]	73.	86.	86.
[illegible]	[illegible]	[illegible]	83.	83.	69.

Table 6-5. (Cont'd)

[illegible]	[illegible]	[illegible]	EXPECTED ARITHMETIC MEAN (MICROGRAMS/CU. METER) 1975	1980	1985
[illegible]	[illegible]	[illegible]	59.	60.	61.
[illegible]	[illegible]	[illegible]	54.	61.	61.
[illegible]	[illegible]	[illegible]	51.	57.	57.
[illegible]	[illegible]	[illegible]	49.	55.	55.
[illegible]	[illegible]	[illegible]	48.	53.	54.
[illegible]	[illegible]	[illegible]	46.	51.	51.
[illegible]	[illegible]	[illegible]	45.	49.	49.
[illegible]	[illegible]	[illegible]	44.	48.	48.
[illegible]	[illegible]	[illegible]	48.	53.	54.
[illegible]	[illegible]	[illegible]	50.	55.	57.
[illegible]	[illegible]	[illegible]	52.	58.	60.
[illegible]	[illegible]	[illegible]	57.	65.	68.
[illegible]	[illegible]	[illegible]	65.	73.	79.
[illegible]	[illegible]	[illegible]	68.	76.	76.
[illegible]	[illegible]	[illegible]	66.	77.	78.
[illegible]	[illegible]	[illegible]	62.	64.	70.
[illegible]	[illegible]	[illegible]	55.	62.	63.
[illegible]	[illegible]	[illegible]	61.	70.	70.
[illegible]	[illegible]	[illegible]	54.	57.	60.
[illegible]	[illegible]	[illegible]	52.	55.	56.
[illegible]	[illegible]	[illegible]	53.	55.	55.
[illegible]	[illegible]	[illegible]	47.	52.	52.
[illegible]	[illegible]	[illegible]	45.	50.	50.
[illegible]	[illegible]	[illegible]	45.	48.	48.
[illegible]	[illegible]	[illegible]	49.	54.	55.
[illegible]	[illegible]	[illegible]	51.	57.	59.
[illegible]	[illegible]	[illegible]	55.	62.	65.
[illegible]	[illegible]	[illegible]	68.	101.	102.
[illegible]	[illegible]	[illegible]	68.	80.	82.
[illegible]	[illegible]	[illegible]	65.	79.	82.
[illegible]	[illegible]	[illegible]	73.	81.	83.
[illegible]	[illegible]	[illegible]	64.	71.	73.
[illegible]	[illegible]	[illegible]	62.	80.	80.
[illegible]	[illegible]	[illegible]	64.	73.	73.
[illegible]	[illegible]	[illegible]	54.	57.	57.
[illegible]	[illegible]	[illegible]	55.	53.	53.
[illegible]	[illegible]	[illegible]	51.	[illegible]	58.
[illegible]	[illegible]	[illegible]	47.	[illegible]	52.
[illegible]	[illegible]	[illegible]	52.	50.	50.
[illegible]	[illegible]	[illegible]	52.	55.	55.

Table 6-5. (Cont'd)

RECEPTOR NUMBER	RECEPTOR LOCATION (KILOMETERS)		EXPECTED ARITHMETIC MEAN (MICROGRAMS/CU. METER) 1975	1980	1985
	EAST	NORTH	PARTICULATES	PARTICULATES	PARTICULATES
[illegible]	[illegible]	[illegible]	[illegible]	55.	56.
[illegible]	[illegible]	[illegible]	52.	58.	59.
[illegible]	[illegible]	[illegible]	56.	63.	65.
[illegible]	[illegible]	[illegible]	59.	67.	69.
[illegible]	[illegible]	[illegible]	59.	62.	69.
[illegible]	[illegible]	[illegible]	61.	69.	70.
[illegible]	[illegible]	[illegible]	61.	69.	70.
[illegible]	[illegible]	[illegible]	59.	67.	68.
[illegible]	[illegible]	[illegible]	59.	67.	68.
[illegible]	[illegible]	[illegible]	54.	57.	69.
[illegible]	[illegible]	[illegible]	55.	62.	63.
[illegible]	[illegible]	[illegible]	50.	55.	56.
[illegible]	[illegible]	[illegible]	48.	53.	54.
[illegible]	[illegible]	[illegible]	45.	50.	51.
[illegible]	[illegible]	[illegible]	45.	43.	49.
[illegible]	[illegible]	[illegible]	44.	47.	47.
[illegible]	[illegible]	[illegible]	49.	55.	55.
[illegible]	[illegible]	3715.0	51.	57.	58.
[illegible]	[illegible]	[illegible]	53.	59.	60.
[illegible]	[illegible]	[illegible]	54.	61.	62.
[illegible]	[illegible]	[illegible]	55.	62.	63.
[illegible]	[illegible]	[illegible]	57.	65.	65.
[illegible]	[illegible]	[illegible]	53.	65.	65.
[illegible]	[illegible]	[illegible]	55.	63.	64.
[illegible]	[illegible]	[illegible]	55.	62.	63.
[illegible]	[illegible]	[illegible]	56.	59.	65.
[illegible]	[illegible]	[illegible]	52.	59.	59.
[illegible]	[illegible]	[illegible]	50.	55.	55.
[illegible]	[illegible]	[illegible]	47.	52.	53.
[illegible]	[illegible]	[illegible]	45.	50.	50.
[illegible]	[illegible]	[illegible]	44.	47.	48.
[illegible]	[illegible]	[illegible]	43.	45.	47.
[illegible]	[illegible]	[illegible]	47.	53.	55.
[illegible]	[illegible]	[illegible]	50.	55.	56.
[illegible]	[illegible]	[illegible]	51.	55.	57.
[illegible]	[illegible]	[illegible]	52.	57.	58.
[illegible]	[illegible]	[illegible]	53.	59.	60.
[illegible]	[illegible]	[illegible]	54.	61.	62.
[illegible]	[illegible]	3740.0	55.	63.	64.
[illegible]	[illegible]	[illegible]	53.	60.	61.

Table 6-5. (Cont'd)

RECEPTOR NUMBER	RECEPTOR LOCATION		EXPECTED ARITHMETIC MEAN (MICROGRAMS/CU. METER) 1975	1980	1985
	[illegible]	[illegible]			
[illegible]	[illegible]	[illegible]	52.	57.	60.
202	[illegible]	[illegible]	53.	60.	61.
203	[illegible]	[illegible]	[illegible]	56.	55.
[illegible]	[illegible]	[illegible]	55.	53.	56.
205	[illegible]	[illegible]	47.	51.	52.
206	[illegible]	[illegible]	45.	49.	50.
[illegible]	[illegible]	[illegible]	53.	47.	50.
208	[illegible]	[illegible]	43.	45.	46.
209	[illegible]	[illegible]	49.	53.	54.
[illegible]	[illegible]	[illegible]	52.	54.	53.
[illegible]	[illegible]	[illegible]	44.	54.	55.
[illegible]	[illegible]	[illegible]	[illegible]	55.	56.
[illegible]	[illegible]	[illegible]	50.	56.	57.
214	[illegible]	[illegible]	52.	54.	59.
215	[illegible]	[illegible]	55.	[illegible]	64.
[illegible]	[illegible]	[illegible]	52.	57.	59.
[illegible]	[illegible]	[illegible]	51.	57.	57.
[illegible]	[illegible]	[illegible]	[illegible]	55.	56.
[illegible]	[illegible]	[illegible]	53.	59.	55.
220	[illegible]	[illegible]	47.	52.	53.
[illegible]	[illegible]	[illegible]	45.	51.	51.
[illegible]	[illegible]	[illegible]	53.	59.	59.
223	[illegible]	[illegible]	44.	[illegible]	47.
224	[illegible]	[illegible]	[illegible]	[illegible]	45.
[illegible]	[illegible]	[illegible]	70.	56.	58.
[illegible]	[illegible]	[illegible]	[illegible]	56.	52.
227	[illegible]	[illegible]	[illegible]	61.	62.
[illegible]	[illegible]	[illegible]	57.	57.	65.
229	[illegible]	[illegible]	51.	55.	57.
[illegible]	[illegible]	[illegible]	[illegible]	65.	56.
[illegible]	[illegible]	[illegible]	65.	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	50.	50.	56.
[illegible]	[illegible]	[illegible]	73.	64.	65.
[illegible]	[illegible]	[illegible]	[illegible]	89.	85.
[illegible]	[illegible]	[illegible]	72.	[illegible]	88.
[illegible]	[illegible]	[illegible]	53.	[illegible]	58.

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7. ANALYSIS OF MODELING RESULTS

Correct analysis and interpretation of the results given by an atmospheric simulation model are essential to the development of adequate control strategies for the attainment and maintenance of the NAAQS. The analysis is made on the basis of four basic considerations:

Magnitude of the problem,
Geographical extent of the problem,
Temporal extent of the problem, and
Identification of sources contributing to the problem.

7.1 PROBLEM MAGNITUDE

7.1.1 Relationship to the Standards

The prime consideration is the interpretation of modeling results is the magnitude of the air quality problem; that is, the amount by which the air quality standards are being violated (if at all). If a simple proportional reduction model has been used, then the projected air quality value for the region is compared to the appropriate NAAQS. If a more sophisticated dispersion model is used, then the computed (and calibrated) concentration at every point is compared to the NAAQS. Upon making this comparison one of three situations occurs:

The computed concentration is well below the standard,
The computed concentration is near the standard, or
The computed concentration is well above the standard.

In the first case, the analysis shows no air quality problem and no further action is necessary. In the third case, some form of control program must be developed, which will bring the concentration down to the standard level. The middle case is the most difficult to interpret and gives rise to the question of how far above (or below) the standard must the calculated concentration be to require that a control strategy be developed (or to determine that none is needed). The simplest approach is to specify a precise limit (e.g., 10% above the standard, 5% above, or the standard itself) that signals the need for strategy development. This is unrealistic and may lead to serious errors in evaluating the situation. A more realistic approach, although much more

difficult to quantify, is to attempt to place confidence limits on the computed concentration values and to use these as a guide to determining the need for control strategies. Figure 7-1 illustrates how this might work. Each of the dots represents a computed concentration level. Receptors 1 and 2 are just above the standard, receptors 3, 4, 6, and 7 are just below the standard, and receptor 5 is at the standard. The bars indicate the estimated range in concentration evaluated by looking at, for example, the possible range of error in the emissions of the major sources contributing to that receptor, or the quality of the calibration at that point. For receptor 1 the confidence bars are narrow, indicating a relatively high degree of faith that the actual concentration will be above the standard and hence a control strategy is called for. For receptor 2 at the same absolute level, the confidence bars are much longer, indicating that there is some possibility that the predicted violation may not occur and that a control strategy may not be necessary. Receptors 3 and 4 are analogous to 1 and 2, respectively, with the analogous conclusions. Receptor 5 is at the standard with confidence bars that indicate that the standard may, in fact, be violated. A control strategy is indicated in this case. The confidence bars on receptor 6 indicate that this is an upper limit on concentration and will not, for all practical purposes, be realized. Such an estimate may be based on worst-case emission patterns. A control strategy is not indicated here due to the extreme nature of the estimate. Receptor 7 is a lower limit and hence has a significant possibility of being an underestimate of the actual case. A control strategy is called for here.

In addition to establishing the degree of confidence in the computed concentrations (based on the accuracy of the data and simulation models), the proposed revisions to the regulations[14] indicate that other factors, such as the degree of completion of abatement activities, year-to-year variations in measured air quality, and frequency of air pollution episodes may be used to judge the magnitude of the problem.

7.1.2 Secondary Standards

By mandate of the Clean Air Act, an air quality analysis must address the attainment of both the primary and secondary standards. The only difference comes in the form of timing of control strategies. The control plan must display a program to attain the primary standards with all reasonable expediency. In cases where the secondary standards cannot be met in the near-term

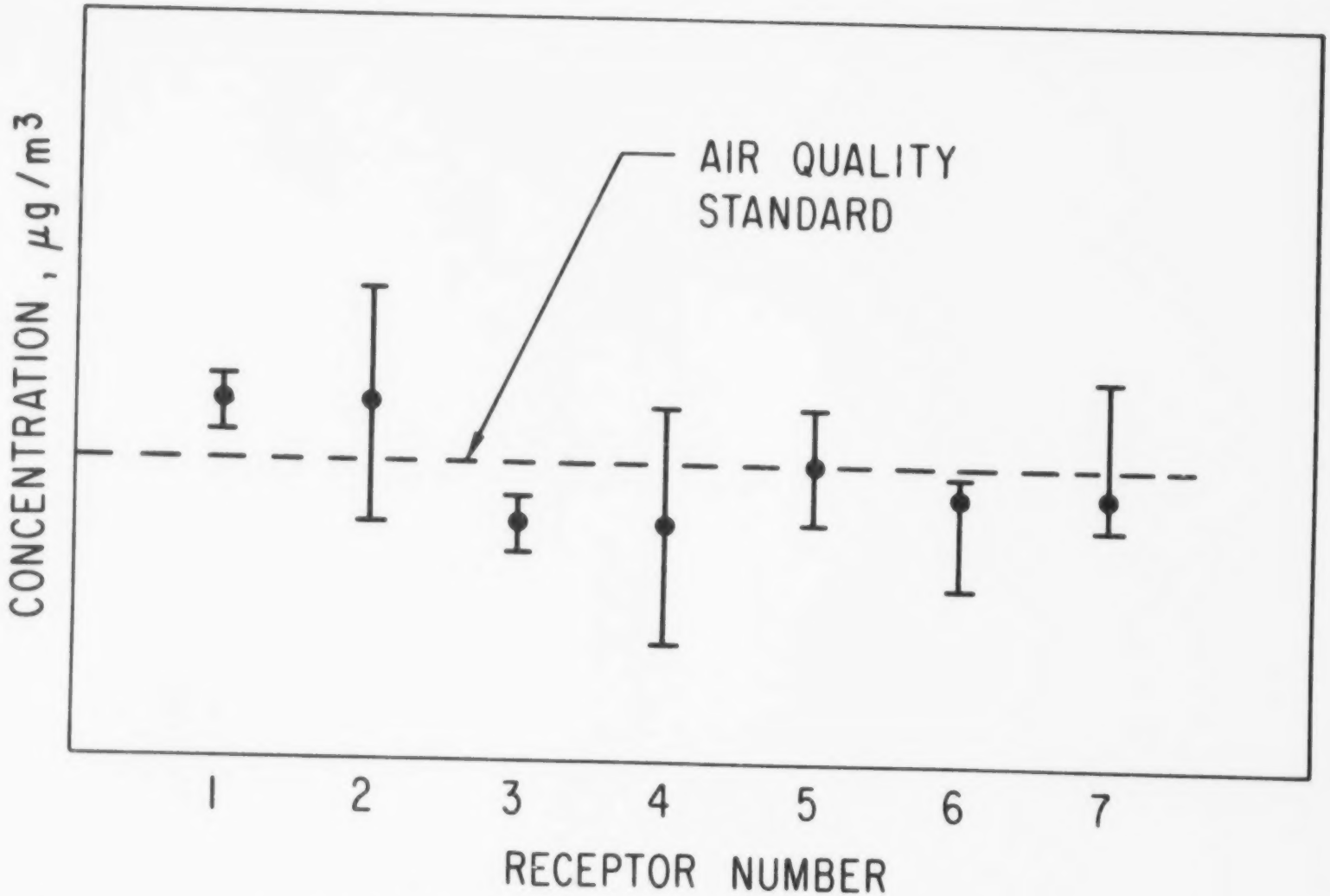


Fig. 7-1. Possible Confidence Analysis for Air Quality Calculations

future due to the lack of appropriate control measures for existing sources, then attainment may be programmed for a more distant date. Regulations relating to "significant deterioration" may, in some areas of the county, prescribe air quality limits more stringent than the secondary NAAQS.

7.2 GEOGRAPHICAL EXTENT

7.2.1 Types of Problems

There are basically two types of geographical air quality problems that will appear in an air quality analysis:

Localized problem
Widespread problem

A localized problem occurs when there is a calculated violation of the NAAQS in only a small subarea of the county. The air quality problem may result from one or a few major sources. The isopleth map of such a situation, illustrated on Fig. 7-2, looks like a small "island" that is over the standard, while the surrounding area is below the standard. The tabulated set of concentrations indicates only one or two receptor locations over the standard.

A widespread problem occurs when large portions of the study area exhibit violations of the standards. This may result from the presence of many sources (large or small) widely distributed over the area and contributing to an aggregate problem although none makes an overwhelming contribution. Also, a high background concentration from natural sources can generate a level that will violate the standards with only small contributions from man-made sources. Figure 7-3 illustrates the isopleth map of such a situation. The concentrations tabulated by a model indicate violations at many receptors.

Frequently, the localized and widespread problems occur simultaneously. In these situations there are widespread violations in the study area upon which are superimposed "hot spots" where the violations become extremely significant as the result of one or more major source contributions. Figure 7-4 illustrates such a situation.

One of the reasons for developing a spatial resolution for emissions that is finer than county-wide is the recognition that control strategies applied to an entire county may not be desirable or needed. In the evaluation

Fig. 7-2. Isopleth of Localized Hot Spot Problem

Fig. 7-3. Isopleth of Widespread Problem

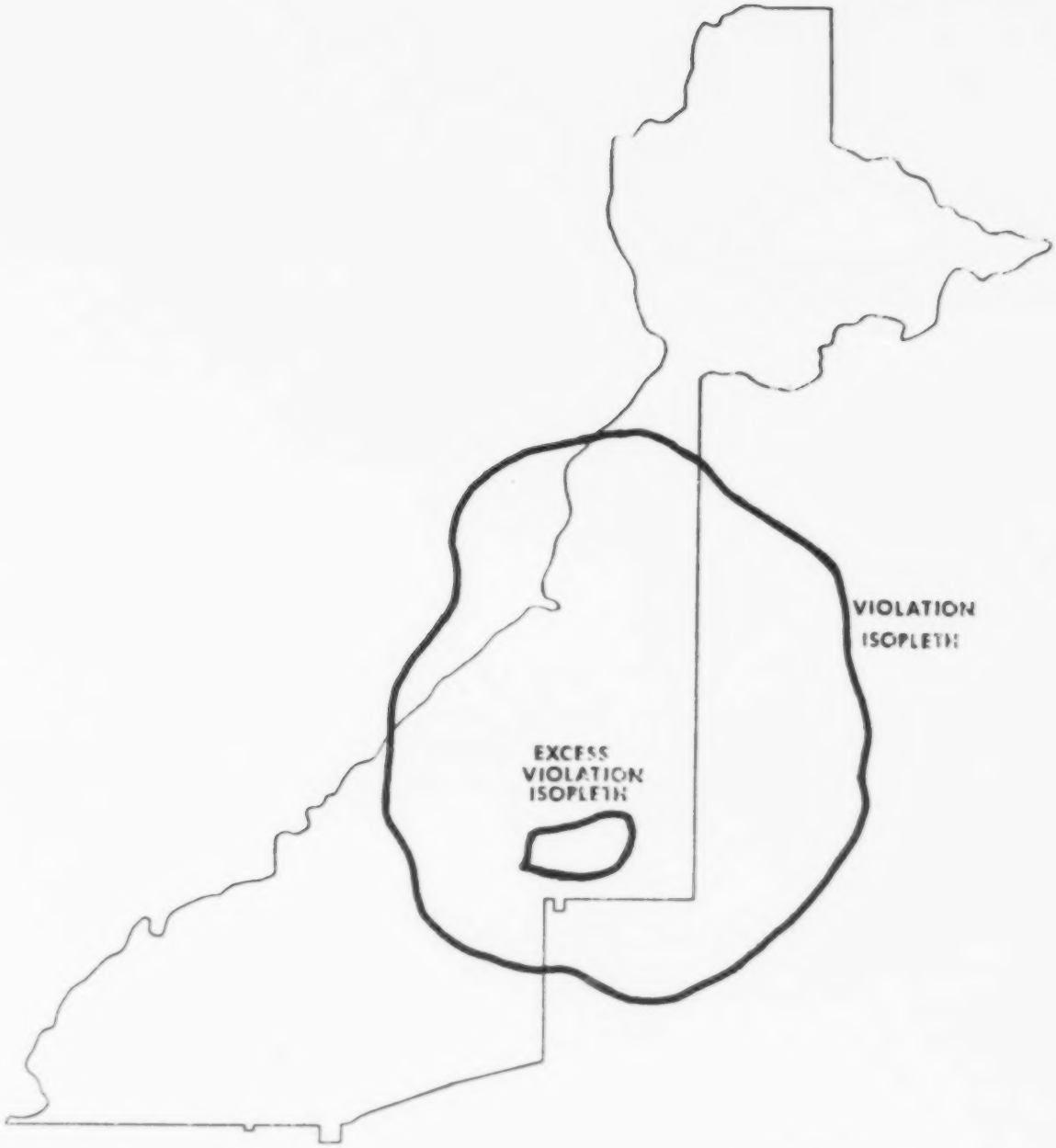


Fig. 7-4. Isopleth of Combined Hot Spot and Widespread Problem

of the modeling results, it is necessary to maintain this spatial distinction and review each subarea for its type of problem.

7.2.2 Boundary Problems

Several complicating situations may arise at the boundary of the study area, which include the following:

Air quality violation outside the study area, and

Air quality violation inside the study area caused by external sources.

The possibilities are exhibited on Fig. 7-5. If the analysis shows that there are violations of the NAAQS outside of the designated study area, it will be necessary to determine the sources contributing to the problem. If the sources are located in the study area, then they must be considered for controls to demonstrate the attainment and maintenance of the NAAQS even outside the specific boundaries of the study area. If the sources are external to the study area, then some consideration must be given to expanding the boundaries to include the newly identified problem area.

If the analysis shows that violations within the study area are being caused by external sources, then these sources must be included as part of the overall control strategy development. In some cases, the results may dictate the expansion of the study area boundaries. These boundary situations will most frequently occur in interstate study areas. In developing control programs, it is necessary that each state's strategy does not interfere with the effectiveness of the adjoining state's. A coordinated effort is required to develop compatible controls.

7.3 TEMPORAL EXTENT

The manner in which the air quality problem varies in time is a strong indicator of the types of control strategies that will be needed to treat the situation. The three types of temporal problems, as illustrated on Fig. 7-6, are the following:

Attainment of NAAQS
Maintenance of NAAQS
Attainment and Maintenance of NAAQS

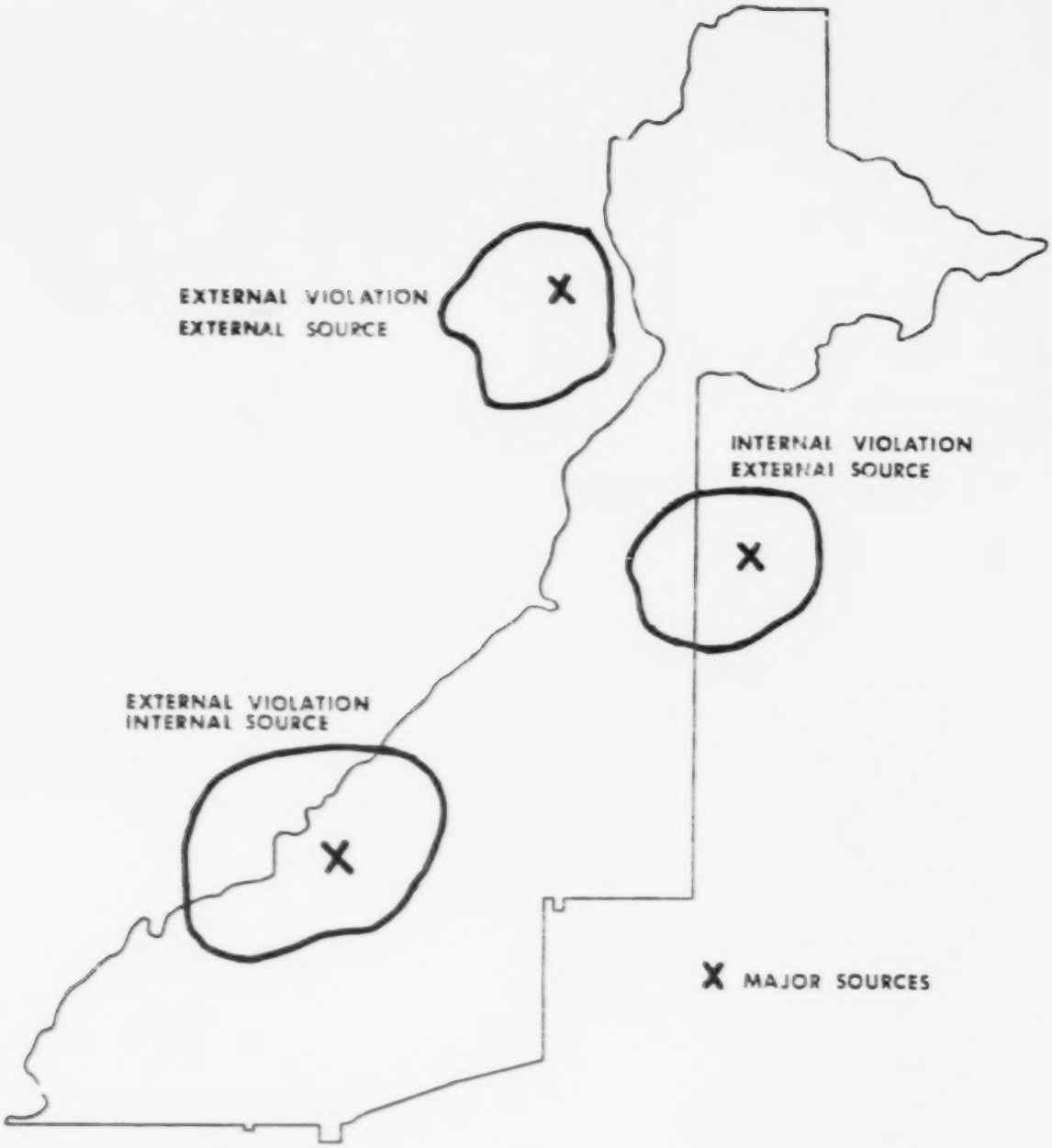


Fig. 7-5. Boundary Problems in an Air Quality Analysis

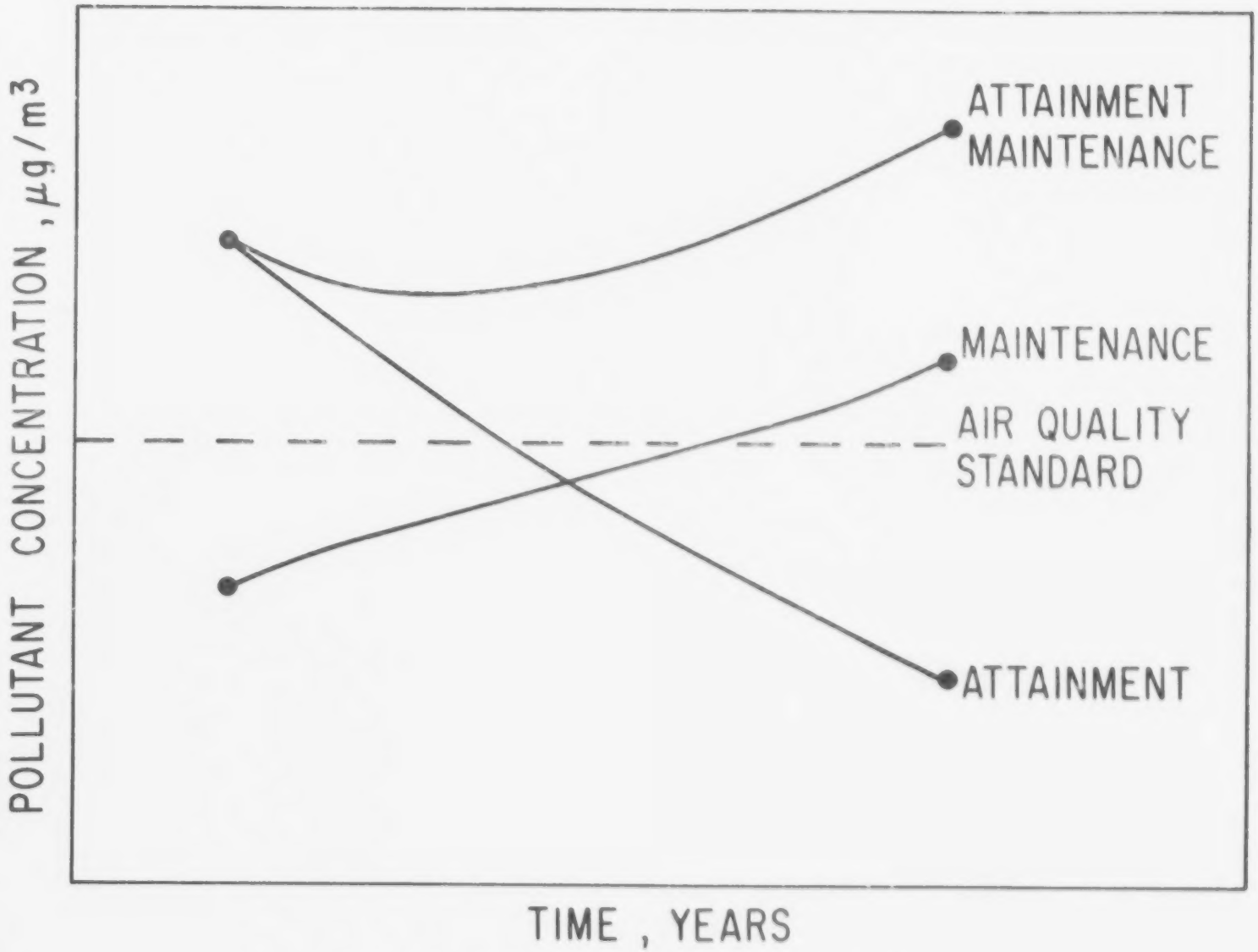


Fig. 7-6. Temporal Extent of Air Quality Problems

Attainment problems are indicated by currently measured violations of the NAAQS. The violations may result from inadequacies of current regulations, non-compliance with current regulations, uncontrollable sources (e.g., fugitive dust), or any one of a number of special situations. Control strategies for attainment problems are focused on existing sources and the adequacy of current regulations. Maintenance problems are indicated by currently measured air quality below the NAAQS, but projected levels exceeding the NAAQS as the result of growth and development. The period over which the standards must be maintained has already been described in Section 4 on projecting emissions (i.e., ten years in areas without another federally-funded planning program and longer in areas with such a program). Maintenance control strategies may be directed toward new and/or existing sources and the development of regulations that can alter the pattern of growth to be compatible with air quality requirements. The combination attainment and maintenance problem is indicated by levels currently above the standards that are projected to deteriorate as the result of growth.

7.4 SOURCE IDENTIFICATION

The identification of sources contributing to the air quality problem has already been discussed as part of the review of model outputs. In the context of this discussion, the only amplification necessary is that the source contributions must be determined as a function of the spatial resolution and the temporal resolution.

7.5 SUMMARY OF AIR QUALITY REQUIREMENTS

At this point in the air quality analysis, it is useful to summarize the problem as it appears. The object is to quantify the emission reductions required to attain and maintain the NAAQS. When using a dispersion model, such as AQDM, that calculates concentrations at any point, one convenient way of displaying the emission reductions is to tabulate the results for each receptor point that is in violation of a standard. Tables 7-1 and 7-2 give the results for selected receptors in the County X computations.

Table 7-1. Source Contribution Analysis for County X

		Receptor 110			Receptor 132			Receptor 151			Receptor 171			Receptor 210			Point Source Compliance Status	
		1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	1975	1980	1985	Baseline Emissions T/yr	Allowable Emissions[a] T/yr
Calculated Air Quality ($\mu g/m^3$)		70	80	80	57	60	68	73	82	83	55	62	63	77	84	80		
% Reduction for:																		
Primary Standard		-	13	12	-				8	10					11	13		
Secondary Standard		15	30	30	-	16	12	17	26	28		1	3	23	29	31		
Source Contributions (%)																		
Points																		
Stone Quarry	#1	1.7	2.0	2.0	8.4	10.0	9.8	2.0	4.4	4.7	1.3	1.6	1.6	3.0	4.7	4.6	7620	6265
	2				1.2	1.4	1.4	5.2	5.2	5.5	6.1	7.3	7.4	1.9	2.3	2.2	529	4130
	3				1.6	1.8	1.8										3425	3115
	4	1.3	1.7	1.8		1.0		2.0	2.0	2.0	1.4	1.7	1.7	1.9	2.4	2.4	5800	3847
	5	27.2	35.1	32.4	13.7	18.0	16.1	9.3	15.6	12.2	4.0	6.6	5.0	12.5	17.3	13.4	16350	9240
	2							1.4	1.3	1.2	8.0	8.2	8.9	1.0			3280	2974
	2			1.1	3.2	2.8	3.7	1.0	1.0	1.3			1.0	1.1	1.0	1.4	6315	3870
Steel Mill	#1	2.1	1.5	1.5				7.3	5.2	5.8				3.1	2.0	2.3	3446	3222
	2	1.2						7.8	5.3	6.0				1.5	1.0	1.1	3446	3222
Lead Smelter		1.4						2.2	1.6	1.3				2.7	1.9	1.6	2530	38
Steam Plant	#1	3.2	3.0	3.7				2.2	2.3	2.7				8.0	7.8	9.3	2322	1103
	2	1.0						1.8						1.8			1205	382
Brick Plant	#1	3.6	3.8	3.8					1.1	1.0				1.2	1.4	1.4	3660	74
	2				1.5	1.6	1.6							1.0	1.1	1.1	3660	74
Concrete Plant	#4								1.4	1.4							50	b
	6								1.6	1.6					1.5	1.5	8	b
Areas																		
	#10	2.2	2.4	2.7	5.4	5.3	6.6	1.9	2.0	2.4	1.4	1.5	1.7	2.1	2.2	2.6		
	77													1.4	1.2	1.2		
	83													1.2	1.0	1.0		
	108					1.0	1.0	1.4	1.3	1.8	7.3	9.1	9.0	1.0	1.3	1.3		
	112							1.4	1.5	1.5	5.8	7.3	7.2		1.1	1.1		
Background		42.6	34.9	35.0	52.5	45.2	44.3	41.3	36.8	35.9	55.0	48.4	47.6	41.2	35.6	34.7		
		87.7	84.2	84.0	87.5	88.1	86.3	86.9	86.7	88.0	92.4	91.7	92.0	87.5	86.8	86.2		

[a]Based on current SIP regulations.

[b]In compliance.

Table 7-2. Detailed Breakdown of Area Source Contributions to Calculated Air Quality at Receptor 151

Year	Area Source Number	Contribution to Calculated Air Quality (%) Area Emission Source Category					Total (%)
		Industrial	Residential	Comm./Inst.	Transportation	Misc.[a]	
1975	10	-	-		-	1.9	1.9
	108	-	-	-	-	1.4	1.4
	112	-	-	-	-	1.1	1.1
1980	10	0.04	-		-	1.96	2.0
	108	0.03	-	-	-	1.87	1.9
	112	0.04	-	-	-	1.46	1.5
1985	10	0.05	-	-	-	2.35	2.4
	108	0.04	-	-	-	1.76	1.8
	112	0.05	-	-	-	1.45	1.5

PROBLEM 7-1

Using the modeling results for County X (Figs. 6-6 to 6-8) and Tables 7-1 and 7-2, evaluate the extent of the air quality problem in terms of magnitude, geographical extent, temporal extent, and source contributions. Determine if additional control strategies are indicated.

8. STRATEGY DEVELOPMENT AND TESTING

8.1 STRATEGIES AVAILABLE

When evaluation of the modeling results indicates that control measures above and beyond the existing regulations and planned federal controls (e.g., NSPS, motor vehicle regulations, etc.) are needed to attain and maintain the NAAQS, there are a battery of techniques available to choose from. These can be divided into two basic groups:

Technological controls and
Land use and planning measures.

Technological controls are those that require emission reductions from specific source categories through the addition of flue gas cleaning devices, changes in process method or equipment, or fuel substitution. Land use and planning measures are designed to redistribute the emission patterns, both spatially and temporally, to achieve air quality improvement. Reference 3 summarizes some of the most common strategies.

8.1.1 Technological Controls

The technological controls available include the following:

New Source Performance Standards,
Existing source retrofit,
Phase-out of emission sources,
Fuel conversion,
Energy conservation,
Combination of emission sources,
Special operating conditions, and
Fugitive dust control.

New Source Performance Standards The federal program of promulgating NSPS under the mandate of Section 111 of the Clean Air Act is designed to insure that all new emission-producing facilities will be equipped with the best available emission control technology at the time of plant design. To date, NSPS have been promulgated for 14 source categories and proposed NSPS exist for 6 others. The on-going program of NSPS development is expected to affect some 250 source categories.[40,41]

The implementation of NSPS is expected to encounter no major difficulties since the regulations are aimed at new or modified facilities only and hence permit the most cost-effective way of incorporating emission controls into plant design. Substantial economic evaluations are included in the NSPS development process to avoid severe financial penalties to the affected industries. The only uncertainty in conducting an air quality analysis taking NSPS into account is the date on which the standards will become effective.

The procedure by which NSPS can be factored into the air quality analysis have already been described in Section 4 on projecting emissions. The NSPS most often influence the required level of control efficiency but may, in some cases, affect the process activity by forcing a conversion from one process to another.

National Emission Standards for Hazardous Air Pollutants (NESHAP) can be analyzed in the same fashion as NSPS. To date, NESHAPs have been promulgated for asbestos, beryllium, and mercury.

Areas affected by Non-Significant Deterioration regulations will place additional NSPS requirements on a group of source categories that can, by the location of a single facility, have a substantial impact on air quality.[42]

Existing Source Retrofit This control strategy is aimed at requiring more stringent emission controls on existing sources. Most State Implementation Plans (SIPs) currently allow higher emission rates for existing sources in recognition of the difficulties and economic penalties associated with retrofit. Implementation of this strategy would require revision of current regulations. Its value is highest in areas requiring NAAQS attainment strategies where existing sources are contributing heavily.

Use of this strategy should be weighed carefully in light of the potential hardships that might be created. Sources that have instituted control programs are likely to strongly resist revision of their objectives and some sources may decide to suspend operation rather than attempt to meet a constantly "moving target." The resources required to engage in the inevitable litigation that would follow such a strategy should also be considered.

This strategy is simulated in the same fashion as NSPS; that is, the control efficiency is influenced by the new standards.

Phase-out of Emission Sources These types of regulations are aimed at ending the activity of a particular source category (e.g., open burning of refuse, coal-fired space heating, etc.). It is effected by prohibiting the replacement of existing sources with the same type of equipment. In an extreme case it could also take the form of increasing the retirement rate of existing sources either by direct regulation (e.g., prohibiting source operation after a specified date) or by some indirect incentive (e.g., tax provisions).

Implementation of this strategy is dependent on two conditions: the availability of alternative processes or services, and the timing of the phase-out schedule. If alternative processes are available and the schedule could be tied to the normal obsolescence rate, then there is minimum impact.

This strategy is simulated by computing emissions from affected sources as zero after their retirement schedule and replacing these with emissions from the new equipment.

Fuel Conversion The switch from a "dirtier" fuel (e.g., coal, residual oil) to a "clean" fuel (e.g., gas, distillate oil) is one of the most widely used control techniques for fuel combustion sources. The shortage of clean fuels has prompted reconsideration of this method and its application only to areas where it is essential to air quality; therefore, in using this type of procedure it will not be adequate to assume that the necessary fuels will be available in unlimited quantity. Also, the control agency may not be able to regulate the distribution of clean fuels since jurisdiction may lie in some other regulatory commission.

The use of fuel switching in a simulation is accounted for by changing the process activity (e.g., from tons of coal to cubic feet of gas) and the corresponding emission factors for affected fuel combustion sources.

Energy Conservation The reduction in the use of fuels and electrical energy results in a corresponding reduction in emissions. A conservation strategy may consist of a number of measures such as:

Changes in building codes to increase insulation,
Greater use of multiple family structures,
Industrial conservation,

Vehicle use constraints, and

Electrical use scheduling.

Some of these measures are, in reality, long-range planning techniques although they address specific source categories.

The implementation of an energy conservation strategy is likely to be exceedingly complex because of the many overlapping jurisdictions of the involved agencies. In most cases, the air pollution control agency will only be able to account for the impact of an energy conservation program in its air quality analysis, but will not be in a position to use it as an enforcable control regulation. Simulation of the effects of such a program involve a reduction of the process activity (i.e., fuel consumption) to reflect conservation.

Combination of Emission Sources The objective of this strategy is to combine many small emission sources into one larger source with a lower overall emission rate. The lower rate is achieved by increased efficiency of resource utilization and by the availability of control equipment applicable only to the larger facility. Examples of this type of technique include district incineration (in which on-site disposal of solid waste is replaced by a larger, well-controlled central incinerator) and district heating (in which a central steam plant or the waste heat from a power plant is used to meet space heating requirements for a large number of small buildings).

This technique has been used on industrial plant sites for many years and has found some applications in urban areas. It almost always appears more cost-effective and efficient to combine sources, but the system is capital-intensive and requires a significant investment on the part of the organization operating the central plant. In a tight money market these investments are not very attractive.

The combined source strategy is simulated by replacing the emissions from the smaller sources (most likely an area source) with the emissions from the larger source (most likely a point source).

Special Operating Conditions Special operating conditions, sometimes referred to as supplementary control systems (SCS), are used to prevent air pollutant concentrations from exceeding the NAAQS under a typical condition

such as start-up and shut-down, malfunction, and adverse meteorological ventilation. An example of such a system would be a regulation allowing a power plant to burn high sulfur fuel during normal conditions and switching to low sulfur fuel during poor meteorological conditions. There are several criteria that have been issued by EPA, which each source desiring to use SCS must meet.[43] They are:

1. Each source must demonstrate that adequate constant emission reduction techniques are not available.

2. Techniques that are available must be applied to achieve maximum practicable emission reductions prior to SCS implementation.

3. A dispersion model must be used to estimate maximum pollutant concentrations.

4. The operator must be willing to accept full legal responsibility for maintaining the NAAQS throughout the area that is significantly influenced by the source.

5. Each source must support and participate in a research and development effort into permanent control systems.

There are only a few sources that would be capable of meeting all the criteria; therefore, its use is extremely limited.

Modeling of this strategy is meaningful only for the short-term standards. The application of a single-source model is necessary to assess the impact of the SCS on air quality.

Fugitive Dust Controls Fugitive dust is an extremely difficult source to regulate because of the widespread nature of the sources (agriculture, unpaved roads, construction, etc.) and the limited control options available. Some areas, especially in the Western portion of the nation, are heavily impacted by fugitive dust and are experiencing substantial problems in NAAQS attainment as a result. In these situations, all reasonably available procedures may be necessary to bring the problem under control. Control efficiencies for the various techniques are given in Reference 27.

There has been some discussion about granting exceptions to some areas where fugitive dust creates severe attainment problems. Such exceptions would require revisions to the Clean Air Act by the Congress and are speculative at this stage.

8.1.2 Land Use and Planning Measures

Land use and planning measures are a much more complex, yet potentially a more powerful, control option than are traditional technological controls. By their nature they cut across many social, economic, and institutional boundaries and have the largest impact on community lifestyles of any environmental control procedure. Land use and planning measures affect air quality control in three ways:

Changing the location of emission sources,
Changing the timing of emission sources, and
Changing the nature, size, or type of emission sources.

These changes can apply to both new and existing sources. It is obvious that each of these changes can have a significant impact on air quality in the light of the previously described considerations necessary to evaluate the extent of the air quality problem; that is, the magnitude, geographical extent, temporal extent, and source contribution pattern of the problem. For example, a projected air quality maintenance problem in a portion of the study area may be treated by encouraging industries to locate in areas that are not as highly concentrated with emission sources, or by postponing development of an area until the shutdown of obsolete, high-emitting sources.

There are numerous implementation instruments that can be used to generate the changes or, stated differently, to adopt a specific land-use measure. They fall primarily into three categories:

Police power regulation,
Public investment policy, and
Tax policy.

Police power regulations are enforceable rules that carry the full weight of law behind them. They require certain performance and their impact on air quality is the most easily measured. Zoning ordinances are the most common form of such regulation. Public investment policy achieves the land use controls using the resource of public funds to acquire land and control development. Tax policies rely on economic incentives to encourage the desired development. These are the most difficult to assess, in terms of air quality impact, because of the unknown elasticities in the reaction of developers to various tax levels. Tables 8-1 and 8-2, drawn from Ref. 44, give a summary description of each of the implementation instruments and their effects on land use measures. The list is comprehensive but by no means all-inclusive.

Table 8-1. Land Use Control Measures and Implementation Instruments

Implementation Instruments	Control Measures: Regulate the Location of New Activities	Change the Location of Existing Activities	Regulate the Timing of the Location of New Activities	Regulate the Timing of the Relocation of Existing Activities	Regulate the Nature/Size/Type of New Activities	Change the Nature/Size/Type of Existing Activities
Public Power Regulation						
[illegible]	X		X		X	
[illegible]	X				X	
[illegible]	X		X		X	
[illegible]			X		X	
[illegible]	X				X	
[illegible]			X		X	
[illegible]	X		X		X	
[illegible]	X				X	
[illegible]	X				X	
[illegible]					X	
[illegible]					X	X
[illegible]			X		X	
[illegible]	X				X	
[illegible]					X	
[illegible]			X		X	
[illegible]					X	X
Public Investment Policy						
[illegible]	X		X		X	
[illegible]			X			
[illegible]	X		X			
[illegible]	X		X			
Public Land Banking						
[illegible]	X		X	X		
[illegible]	X	X	X	X	X	X
[illegible]						X
[illegible]				X		X
[illegible]		X		X		X
[illegible]	X	X		X	X	
[illegible]	X	X	X	X	X	X

Table 8-2. Land Use Implementation Instruments

Police Power Regulation

Agricultural/Conservation Zoning: Land deemed valuable for agricultural or open space use is zoned exclusively for the use of agriculture or conservation. In the case of conservation zones, construction upon or alteration of these significant natural areas is prohibited.

Conditional Zoning: Involves the reclassification of a single applicant's property to another zoning district coupled with the imposition of conditions designed to ameliorate the impacts of the new district on neighboring properties.

Development Districts: Development districts are viewed as one step in a staged development process for regulating development in areas having the earliest programmed dates of development. They are usually located in predominately undeveloped areas and should be large enough to justify the cost and effort of establishing a special governmental institution and to offer economies of scale. It adopts many of the positive aspects associated with the development of new towns, including the abilities to assemble land, control capital and take the initiative to organize necessary public and private activities, coordinate them, and program their participation.

Emission Density Zoning/Emission Allocation Planning: A regulation that requires emissions of a pollutant to be limited to prescribed levels within defined spatial areas. A limit is established in terms of an amount of emissions per area per time period, such as pounds of particulates per acre per year.

Floating Zone: A special use district is defined but is not applied to a given area, until a developer asks the planning authority to rezone a particular piece of land in that category. Floating zones may specify minimum land area allowed before development is permitted.

Holding Zones: A form of police power regulation that operates to postpone development over a 3- to 4-year time frame. Only rural residential or agricultural uses would be permitted. In some cases, may require payment of compensation.

Incentive Zoning: Elements to encourage developers to meet certain city desires or criteria; for example, lot consolidations and large-scale developments could be encouraged by allowing greater densities.

Interim Zoning Ordinances: Preliminary version of a future comprehensive plan that is used to freeze the status quo prior to the completion of a comprehensive plan. Subject to many legal complexities.

Large Lot Zoning: Areas considered valuable for their natural resources, agricultural or open-space potential, or difficult to service land, are designated for very low density (minimum 1-5 acres) single-family residential or agricultural use.

Table 8-2. (Contd.)

Police Power Regulation (Contd.)

Moratoria: Sewer/Transportation/Building/Plan Completion: Temporary halts to new development pending completion of a plan, construction of facilities, enlargement of sewer capacity, etc.

Performance Standards: Standards to control impact rather than use. The ambient standards approach establishes a level of a particular residual that will be tolerated within a community and then sets standards for the emissions sources that will allow the community to attain the desired level of ambient air quality. An emissions regulation approach regulates emissions at the stack.

Permits: Permits required for specified uses to provide more specific controls. May be used to regulate uses that can have an adverse impact at the neighborhood level.

Phased Zoning: In order to avoid the problem of property being rezoned for one purpose, only to have the developer fail in his/her representations by not conforming to the proposed plan, property may be rezoned on a phased basis. The rezoning could become effective on a phased basis by rezoning the first 2 acres immediately and providing that the second 2 acres are to be rezoned automatically upon completion of the development of the first segment.

Planned Unit Development: A land development project comprehensively planned as an entity via a unitary site plan that permits flexibility in building, siting, mixtures of housing types and land uses, usable open spaces, and the preservation of natural features.

Subdivision Regulations: Regulations that specify the conditions for dividing new land into lots and offering it for sale. Exercised under the police power, they govern the preliminary stages of development: street layout, specifications, and installation of services, etc.

Transfer of Development Rights: A concept that has been developed to preserve historical landmarks and unique environmental areas. The unused development potential over or next to a landmark, or in a unique area, is purchased by the city (or other jurisdiction) and placed into a development rights bank. A transfer district is established that can absorb increased densities and developers within this new district are given the opportunity to purchase development rights from the bank and build a density that is more intensive than normally permitted.

Transitional Zones: A zone that allows for a buffer between abutting zones with mixed or special uses therein.

Public Investment Policy

Adequate Public Facilities Ordinances: A requirement to regulate the timing of development until adequate sewer/road/mass transit facilities have been constructed.

Table 8-2. (Contd.)

Public Investment Policy (Contd.)

Capital Improvements Programming: The timing of capital improvements programs can be coordinated with environmental considerations and projected development patterns. Similarly, capital improvements programs can be used to direct the location and timing of new development.

Public Land Acquisition:

Installation Purchase: Allows the county to acquire more land on limited funds, and establishes a fair market price before development pressures occur.

Purchase with Rights of Life Estate: If land is needed for future use, it can be reserved by granting life estates, also lowering acquisition costs.

Purchase and Resale: By purchasing land and then reselling it, the public agency can place restrictions on the future use of the land at the same time as it is kept in productive use and on the tax rolls.

Purchase and Leaseback: By purchasing land and then leasing it back, the public agency is both able to regulate use and recoup some of its expenses and tax revenue losses.

Public Land Banking: Land banking involves the public purchase of land prior to its actual use. The Federal Redevelopment and Housing Authorities Act, the Sanitary Districts Law, and the Open Space Land Act enable local governments to use land banking for the specified purposes of housing and conservation in redevelopment areas, for facilities related to sanitation, and for open space acquisition.

Taxation Policy

Capital Gains Tax Policy: The capital gains tax policy operates in such a way as to encourage the purchase and holding of land by investors. Large transfer taxes could be imposed when land that had low priority tax rates due to deferment was sold to recover funds for local areas.

Differential Assessment:

Preferential Assessment: Land devoted to agricultural use is assessed on the basis of its value in that use. Requirements vary as to the length of time that the land must remain in agricultural use. Local governments have no choice but to grant assessment if landowner meets requirements of the statute. No penalty for future changes.

Table 8-2. (Contd.)

Taxation Policy (Contd.)

Differential Assessment (Contd.):

Restrictive Agreements: Local governments make agreements with landowners whereby the landowner agrees to restrict use of land for a period of years in return for tax concessions. Similar to tax deferments, although restrictive agreements extend over a longer period of time.

Tax Deferment: Provides for assessment according to value in current use, but adds a charge when land is transferred out of farm use.

Estate/Gift Tax: Estate/gift taxation may operate to put pressure on the owner to accumulate and maintain a greater degree of liquidity and may also lead to the breakup or disposition of family farms and land holdings. The estate tax savings from charitable bequests encourages transfers of real estate to charitable and public use.

Income Tax Policy: There are many aspects of federal income tax policy that, inadvertently, have a wide effect on land use. Income tax policy affects land use through accelerated depreciation methods, creating an incentive for quick turnover and incentives for owner-occupied housing. The deductibility of the property tax for income tax purposes lessens its burden. Depreciation capital gain, homeowner benefits, and other features stimulate investment and land-use in ways that may be seen to encourage horizontal growth.

Increased Rate of Amortization: Allow industries to increase the rate of amortization of equipment in order to encourage the phasing out of older, more obsolete equipment, and to encourage the installation of necessary pollution control technology.

Property Tax Policy: Property taxes are levied against the value of the entire real estate parcel land plus improvements. It is the current market value for the parcel in its present use that is generally assessed. Property taxation is the chief source of local government revenue and influences land prices, land uses, and the urban development patterns.

Tax Incentives: Decreasing the assessment rate or the assessed valuation for particular uses, tax deferment, special tax rates/credits, subsidies, can encourage the location of certain uses.

8.2 CHOICE OF STRATEGIES FOR ANALYSIS

8.2.1 Strategy Screening

With the multitude of control options available, it is evident that resources will not permit an agency to evaluate all of them. Also, many of the strategies will not be applicable to the problems encountered. A screening process is needed to identify those control options that should receive detailed analysis and that should be rejected as unworkable. Figure 8-1 indicates one approach to this process.

The primary screen is the scope of the problem as indicated by the modeling results. The magnitude, geographical extent, temporal extent, and source contributions will eliminate many strategies that are not applicable. The availability and accuracy of the data used to develop the analysis will influence the choice of strategy. Some judgment must be made as to whether the available information is adequate to support conclusions that might be drawn from an analysis of a given strategy. For example, an analysis based on level 1 emission projections and a rollback model would not be sufficiently detailed to draw any meaningful conclusions about the effects of a taxing policy. In some instances, the desirability of a strategy may warrant an iteration to improve the data base and analysis method. Hopefully, this type of major reworking will not be necessary as the result of a careful level of detail analysis carried out prior to the major efforts.

Some strategies may be eliminated on the basis of social, economic, or institutional constraints without the necessity of a detailed evaluation of these considerations. Agencies participating in the air quality analysis should have the experience to know which options are unacceptable for the study area.

Resource constraints will enter into the screening process at this point. If the available options are still too numerous for the agency to evaluate all of them, then the most promising can be selected with the remainder held in abeyance in the event that the chosen ones turn out to be inadequate.

As with the rest of the air quality analysis, the selection of strategies for evaluation is an iterative procedure and the first guesses need not preclude consideration of other options.

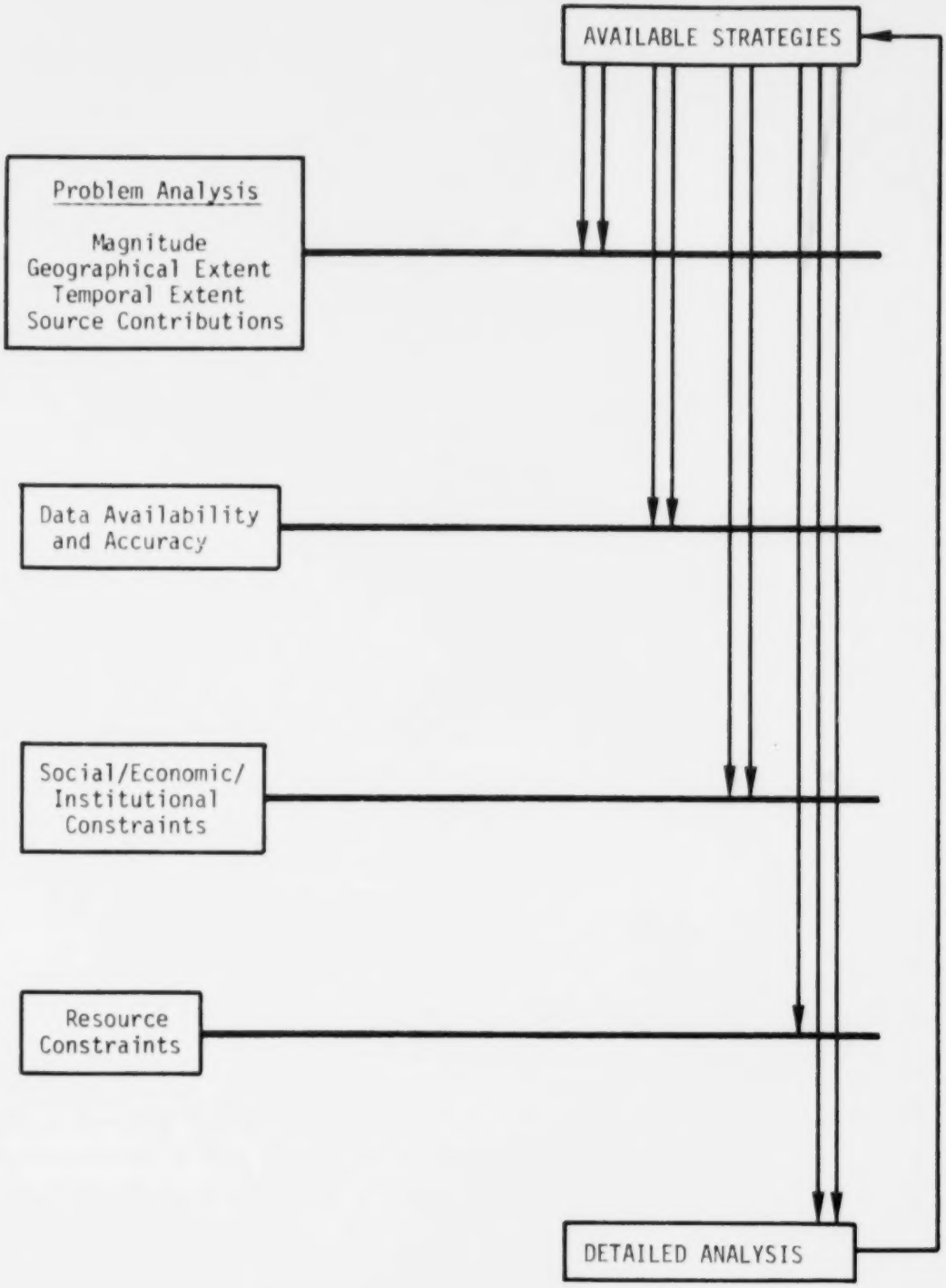


Fig. 8-1. Screening of Strategies for Detailed Evaluation

8.2.2 Special Considerations

Number of Strategies Chosen In general, more than one option should be considered for each problem situation. This will give the agency a perspective on the range of possibilities that could be employed to attain and maintain the NAAQS. It also gives the agency a contingency plan in the event that a particular option is found to be unacceptable at some later point. As an example, control of a single large source could be approached through tighter emission limits, phase-out of the source's operation, or relocation of some of the source's emission-producing processes. The number of strategies to be considered is a function of available resources.

Applicability of Controls It should be recognized that control strategies need not be applied uniformly across the study area. Certain subareas may require stricter controls or different types of controls. The main reason for going to a subcounty allocation of emissions[13] is to achieve enough spatial resolution to allow for varying strategies. In this vein, one point must be remembered: the provisions of equal protection under the law creates some difficult problems in enforcing source-specific regulations. This must be factored into regulation design.

Synergistic Effects The interaction of strategies is an important decision parameter in selecting control options for evaluation. The possibility of a synergistic effect, wherein two strategies together generate more (or less) control than each of them separately, must be considered.

Coordination with Other Agencies The coordinated effort between air pollution control, regional planning, transportation planning, and other groups is an underlying assumption for the entire air quality analysis system. The regulations require that the agency taking the lead role in the analysis consult with other groups as necessary. The choice of strategies for evaluation is one of the most crucial points at which this consultation takes place. It should be remembered that this is only an initial screening of alternatives and continuing review of the strategy options should involve all concerned groups. It may be desirable to implement a structured decision-making process, such as Delphi or WERC, which will be described in more detail in Section 9.

Technological Controls vs. Land Use Measures Traditional air pollution control programs have relied on technological controls to achieve desired air quality levels. The maintenance of the NAAQS requires the addition of non-traditional considerations such as the land use and transportation planning measures. In choosing strategies for evaluation, both options should be considered; however, the availability of emission control technology should be taken as the prime consideration. If all sources are not controlled to the most reasonably available control technology level or best available control technology level, serious questions as to the equity of the air quality management program may be raised. Also, land use control measures are, in general, significantly more difficult to implement and enforce; therefore, the use of technological controls are given first consideration in strategy choice.

This does not intend to minimize the importance of land use and planning controls in air quality management. Rather, it is designed to emphasize that air pollution control is only one of a number of factors that influence land-use decisions and the air quality analysis is not designed to address all of the factors. By employing the most reasonably available control technology first, the impact of air quality constraints on land-use plans can be minimized.

Inforcement vs. New Controls In some cases, air quality problems are not being generated by inadequate regulations but rather by non-compliance with existing regulations. Therefore, prior to the consideration of developing new control programs, it is necessary to review the enforcement of the current programs. It should be a first priority in the air quality analysis to determine if enforcement of existing regulations could achieve the air quality goals. Only after it is determined that full compliance with current regulations is inadequate to attain and maintain the NAAQS should effort be expended on developing new control programs.

PROBLEM 8-1

With the data available from the modeling results for County X (Section 7) develop a list of potential control strategies that might be evaluated in detail as part of an air quality analysis.

8.3 INTERPRETATION OF STRATEGIES INTO MODELING TERMS

The strategies chosen for detailed evaluation must be interpreted into the terms of the atmospheric simulation model to evaluate their effectiveness in attaining and maintaining air quality.

8.3.1 Technological Controls

Technological controls are the easiest to interpret into the form necessary for modeling. The procedures follow those that have been outlined in Sections 3 and 4 on developing a baseline and a projected emission inventory. The following equation is the key item:

$$\text{Emissions} = \begin{matrix}\text{Process}\\ \text{Activity}\end{matrix} \times \begin{matrix}\text{Emission}\\ \text{Factor}\end{matrix} \times \left(1 - \begin{matrix}\text{Control}\\ \text{Efficiency}\end{matrix}\right) \qquad (8\text{-}1)$$

In applying this equation to each source category, a technological control will most frequently result in a change in the control efficiency. It is also possible to change the process activity and/or the emission factor by changing the process itself (e.g., fuel switching).

In determining the level to which each source can be controlled, the preliminary New Source Performance Standards list[28] can be used as a guide to the upper limit of best available control technology. It should be remembered that these levels represent an estimate of what might be reasonably expected from new sources and, in general, it will not be practical to expect these control levels of existing sources.

In evaluating technological control strategies, it becomes immediately obvious that there are a multitude of calculations to be performed. Each control option may be applied to different source categories and there are numerous combinations of strategies that might be tried. It is often desirable to develop a computerized control strategy model that will scan the emission inventory, apply the necessary control strategy to each source, and compute emissions. Such a model is currently under development.[45]

PROBLEM 8-2

For the clay products industry of Problem 4-1, determine the effect on emissions of each of the following strategies: (a) retrofitting existing sources to New Source Performance Standards beginning in 1980, (b) retrofitting existing sources to a level halfway between NSPS and current emission levels beginning in 1980, and (c) accelerated phaseout of older equipment.

PROBLEM 8-3

Estimate the emission reduction possible in County X by using central district heating in a portion of the county. Assume that 10,000 new single-family homes will be built to use central district gas heat instead of individual gas heat. The estimated efficiency of the central plant will reduce fuel consumption by 15%. What particulate control efficiency would be needed to permit the use of residual fuel oil in place of gas in the central plant without increasing emissions over the level resulting from individual gas heat? The following data are given:

Home annual heat requirements	50.7×10^6 Btu/yr/home
Individual home heating gas efficiency	80%
Central heating plant gas efficiency	95%
Central heating plant residual oil efficiency	89%
Gas heating value	1,050 Btu/ft^3
Residual oil heating value	150,000 Btu/gal
Individual home heating plant gas emission factor	10 lb/10^6 ft^3
Central heating plant gas emission factor	10 lb/10^6 ft^3
Central heating plant residual oil emission factor	23 lb/10^3 gal

8.3.2 Land Use Measures

It is a much more complex problem to evaluate the effect of land use measures on emission levels. It is, however, possible to treat the problem in a generic sense; that is, to determine the extent to which the location, timing, and nature, size, or type of the emission sources must be changed to achieve compatability with the NAAQS without specifically addressing the implementation instrument that will be used to achieve the desired emission pattern. This approach defines the bounds of the problem within which the implementation instruments must operate.

Emission Quotas One of the concepts most frequently used to study the effects of land use measures on air quality is that of an emission quota.[46] Stated simply, an emission quota is the maximum allowable emissions that could be tolerated in any given area without violation of the NAAQS. This maximum allowable emission rate is tempered by considerations of the assimilative capacity of the atmosphere (i.e., the meteorological conditions in the area) and the conditions of emission discharge (i.e., considering items such as stack height, etc.). If it were possible to uniquely define this emission quota, it would then be possible to develop a variety of control programs and regulations that would meet the quota and thereby meet the NAAQS. Experience has shown that it is not a simple task to define the quota in a fashion that addresses all the issues; nevertheless, it is possible to develop some working relationships that can be used in air quality management planning.

One technique of determining an emission quota is to define an upper limit on emissions for a jurisdiction or a region using a proportional reduction calculation. This is the same procedure as using a rollback model. The air quality at the worst receptor is compared to the NAAQS and the ratio of the air quality to the standards is used to determine the ratio of the allowable emissions to current emissions. For example, if the worst receptor is over the standard by 50% of the difference between the standard and the background, then emissions must be reduced by 50% in order to attain the NAAQS. Similarly, if the worst receptor is below the standard by 25% of the difference between the standard and the background, then a 25% growth in emissions is tolerable before the NAAQS will be violated.

The emission limit may also be determined by using a dispersion model, instead of rollback, to compute the air quality constraints. In this case, each computed receptor is reviewed to determine the fractional decrease (or increase) in emissions that is compatible with the NAAQS. The use of a tabulation similar to that on Table 7-1 would be helpful in making this determination. Also, it is more convenient to use only area sources in the model. Point source emissions are allocated to the grid cell in which they occur and the area sources then contain all emissions.

A third alternative is to use an optimization model, such as a linear program, to determine the maximum allowable emissions from a set of grid cells subject to the constraint of the air quality complying to the NAAQS. This will be reviewed in more detail in the discussion of emission density planning.

Once the emission limits are determined for the region, county, subarea, or grid cell, either by one of the above methods or by some other formulation, the control strategies can be developed to insure that the limits are not exceeded. For example, new sources may require a permit to locate in a given subarea. The permit is issued upon demonstration that the source will not exceed the subarea's emission quota. As another example, a land use plan for a region is reviewed to project the expected emissions in each subarea. The plan is determined to be compatible with air quality considerations if the emissions in each subarea are less than the quota for each subarea.

This description of emission quotas is often referred to as Emission Allocation Planning (EAP). A variation of EAP is the Floating Zone Emission Quota (FZEQ). In this formulation the emission limit is prescribed for any area of specified size within the study region. Using the example of Reference 46, if it is determined that the control strategy will require no emission level greater than 2000 tons/year in any square mile of the study area, then a source whose expected emission rate was 200 tons/year would have to locate in an area where the emissions from other sources within a square mile totaled less than 1800 tons/year. This concept may be extended to use an air quality measure rather than an emission measure. In this situation a "footprint" of the expected impact of the source alone (i.e., an isopleth of the single source) would be used to identify locations where the source could be sited such that its air quality impact, when added to that of surrounding sources, would meet the NAAQS. It is evident that the FZEQ strategy, in either form, is of primary use in locating potential sites for new facilities.

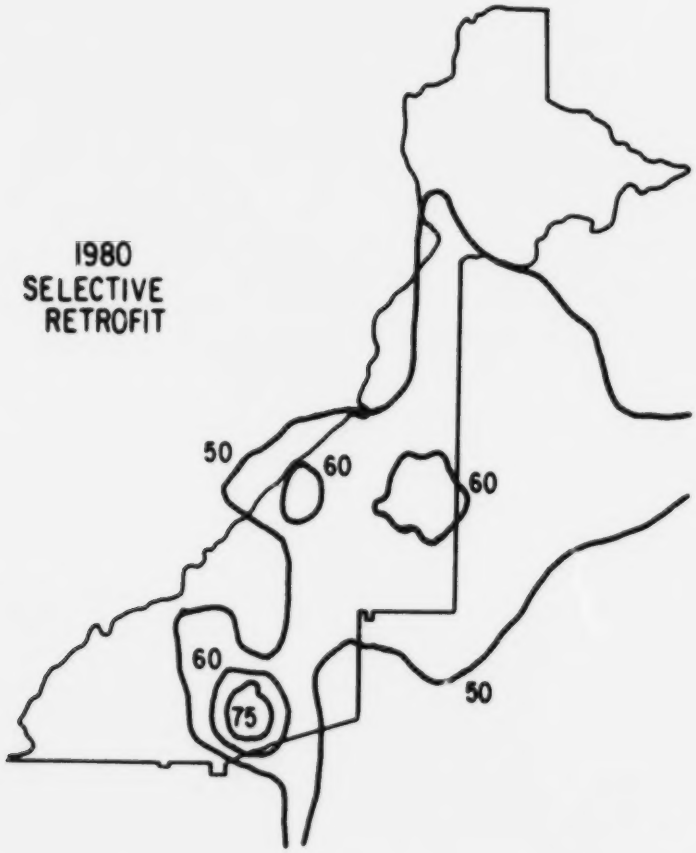
PROBLEM 8-4

Given the following data, develop an emission quota for each of the subareas using a proportional reduction calculation. What are the possible alternatives to developing the quota.

Receptor	Calculated Concentration ($\mu g/m^3$)	Subarea	Subarea Emissions (tons/yr)	Subarea Contribution to Computed Air Quality (%)
X	80	1	14,500	1
		2	11,890	3
		3	5,160	2
		4	38,700	7
		5	1,100	1
		6	3,000	20
		7	12,300	11
		8	2,130	2
		9	9,800	4
		10	12,000	4
		11	25,000	2
		Background		43

PROBLEM 8-5

Isopleths of projected 1980 particulate concentrations assuming a selective retrofit strategy and the "footprint" of a 100-T/day source are shown on Fig. 8-2. (a) Where can this source be located in County X in 1980? (b) Where can a 10-T/day source be located?



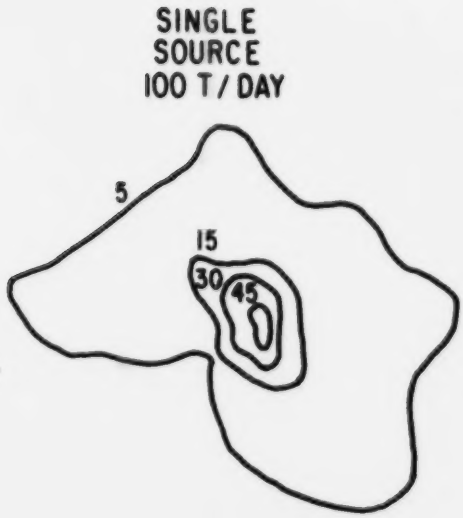


Fig. 8-2. County X Isopleths and Single Source Footprint for Problem 8-5

Emission Density An alternative method for developing an estimate of the maximum allowable emission rates is the use of an emission density approach rather than an absolute emission quota. This technique, often referred to as Emission Density Zoning (EDZ), prescribes limits on the maximum emission density, measured in tons of pollutant per acre per year, on various portions of the region. The emission density concept is more flexible than emission quotas in that it allows a source to locate in a given area if it can demonstrate that enough buffer zone will be available to prevent a clustering of sources, which would result in a violation of the NAAQS. It may be combined with single source regulations (e.g., new source standards, stack height regulations, etc.) to prevent a NAAQS violation resulting from a large single source, which can generate local air quality problems by itself.

As with the establishment of emission quotas, the determination of the maximum allowable emission density from each portion of the study area is a difficult process subject to many interpretations of the most important issues. The problem may be formulated in the following way. The primary constraint is that the air quality at every receptor must satisfy the NAAQS. The conceptration is computed by Eq. (8-2):

$$\text{Concentration at Receptor } i = \text{Sum of the Contributions from all } k \text{ subareas} \tag{8-2a}$$

$$C_i = \sum_k a_{ik} E_k \tag{8-2b}$$

where a_{ik} is a coupling coefficient or, stated otherwise, is the contribution of area k to the air quality at receptor i, assuming a unit emission rate of 1 T/yr.

These values may be calculated by running a dispersion model (e.g., AQDM) with an emission rate of 1 T/yr for all k areas. The culpatibility list (e.g., Fig. 6-3) will then display this information. E_k is the total emission rate in area source k in T/yr.

The product of a_{ik} and E_k is the contribution of the sources in area k to the concentration at receptor i and is entirely analogous to the information determined by the normal culpatibility list. The total concentration is just the sum of the contributions from all sources. This may be said since

the principle of superposition applies. The total concentration must be less than the appropriate NAAQS (e.g., 75 $\mu g/m^3$ for annual average particulate concentration). This is expressed by Eq. 8-3:

$$C_i \leq S \tag{8-3a}$$

$$\text{or} \sum_k a_{ik} E_k \leq S \tag{8-3b}$$

where S is the standard.

In this formulation the values of a_{ik} are fixed and are a function of the meteorology only (e.g., wind rose, mixing height, etc.), since they assume a unit emission rate from all areas. The value of S is fixed by the NAAQS. Hence the problem has k unknowns (i.e., the values of E_k that would satisfy the air quality constraint) but only one equation for each receptor point. This means that there are an infinity of solutions. Interpreted in practical terms, there are an infinite number of ways one could increase emissions from one area and decrease emissions from another area while still satisfying the NAAQS. To obtain a unique solution to the problem it is necessary to impose some additional constraints to limit the number of possible combinations of E_k that can be used. Herein lie the most difficult aspects of the problem. There are numerous additional constraints that can be considered, each of which can result in a different solution. For example, it may be desired to force the solutions for E_k to be greater than some minimum value and/or less than some maximum value. This would be simulated by Eq. (8-4):

$$(E_k)_{min} < E_k < (E_k)_{max} \tag{8-4}$$

This can be interpreted as stating that emissions in the area k will not fall below a certain level because of existing emission-producing activities that are not expected to shut down. A maximum emission level might indicate the desire to preserve a relatively emission-free zone (e.g., a residential zone, park, etc.)

Another example of an additional constraint is to require the solution to maximize the total emissions in the region. That is:

$$\sum_k E_k = \text{maximum} \tag{8-5}$$

This can be interpreted as allowing the greatest degree of development in the region while still meeting air quality standards.

Still other forms of additional constraints might include maximizing emissions in one area while minimizing them in another, requiring that emissions in adjacent zones vary by only a designated amount to avoid generating a solution that will place a heavily developed industrial zone next to a residential zone, or attaching economic weighting factors to the emission level in each zone and forcing the solution to a least-cost mode.

It is also possible to combine more than one set of additional constraints to further refine the solution. The imposition of too many constraints may result in no available solution that satisfies them all; hence, some judgment must be exercised.

A linear program may be used to arrive at a solution to Eq. (8-3) subject to the constraints of Eq. (8-4), (8-5), or any others imposed. A standard computer package is available[47] that may be employed or any one of a number of other linear programming techniques may be applied.[48] The linear program essentially performs a series of iterative calculations to determine the solution functions (i.e., the values of E_k).

At this point it is possible to use the output values of E_k as absolute emission quotas (i.e., tons/year) and follow the strategy procedures previously described. Using the same formulation with a modified interpretation of E_k as an emission <u>density</u> (i.e., tons/acre/year) with a corresponding interpretation of the coupling coefficients, a_{ik}, as the air quality impact on receptor i of a unit emission <u>density</u> in area k, it is possible to use the solutions for E_k as maximum allowable emission densities for each area. This information may be integrated directly into the air quality management planning process. For example, if the solution indicates that maximum allowable emission density in an area is 2 tons/acre/year, then an industrial plant having an emission rate of 200 tons/year and desiring to locate in that zone would have to purchase at least a 100-acre site or would have to reduce its emissions in proportion to a smaller lot size.

Figures 8-3 and 8-4 illustrate the output of a linear program solution for County X. Equation (8-3) was subjected to constraints represented by Eq. (8-4) and (8-5). The minimum emissions allowed in each zone reflected

EXECUTION. [illegible]

SECTION . - ROWS

PAGE [illegible] - 75/308

NUMBER	...ROW...	ST	...ACTIVITY...	SLACK ACTIVITY	...LOWER LIMIT.	...UPPER LIMIT.	.DUAL ACTIVITY
1	TOTALEM	BS	[illegible]	[illegible]	NONE	NONE	1.00000
2	RCPT1	BS	[illegible]	[illegible]	NONE	75.00000	.
3	RCPT2	BS	[illegible]	[illegible]	NONE	75.00000	.
4	RCPT3	BS	[illegible]	[illegible]	NONE	75.00000	.
5	RCPT4	BS	[illegible]	[illegible]	NONE	75.00000	.
6	RCPT5	UL	[illegible]	.	NONE	75.00000	.
7	RCPT6	BS	[illegible]	[illegible]	NONE	75.00000	1.73838-
8	RCPT7	BS	[illegible]	[illegible]	NONE	75.00000	.
9	RCPT8	BS	[illegible]	[illegible]	NONE	75.00000	.
10	RCPT9	BS	[illegible]	[illegible]	NONE	75.00000	.
11	RCPT10	BS	[illegible]	[illegible]	NONE	75.00000	.
12	RCPT11	BS	[illegible]	[illegible]	NONE	75.00000	.
13	RCPT12	BS	[illegible]	[illegible]	NONE	75.00000	.
14	RCPT13	BS	[illegible]	[illegible]	NONE	75.00000	.
15	RCPT14	BS	[illegible]	[illegible]	NONE	75.00000	.
16	RCPT15	BS	[illegible]	[illegible]	NONE	75.00000	.
17	RCPT16	BS	[illegible]	[illegible]	NONE	75.00000	.
18	RCPT17	BS	[illegible]	[illegible]	NONE	75.00000	.
19	RCPT18	UL	[illegible]	.	NONE	75.00000	.73154-
20	RCPT19	UL	[illegible]	.	NONE	75.00000	.14694-
21	RCPT20	BS	[illegible]	[illegible]	NONE	75.00000	.
22	RCPT21	BS	[illegible]	[illegible]	NONE	75.00000	.
23	RCPT22	BS	[illegible]	[illegible]	NONE	75.00000	.
24	RCPT23	BS	[illegible]	[illegible]	NONE	75.00000	.
25	RCPT24	BS	[illegible]	[illegible]	NONE	75.00000	.
26	RCPT25	BS	[illegible]	[illegible]	NONE	75.00000	.
27	RCPT26	BS	[illegible]	[illegible]	NONE	75.00000	.
28	RCPT27	BS	[illegible]	[illegible]	NONE	75.00000	.
29	RCPT28	BS	[illegible]	[illegible]	NONE	75.00000	.
30	RCPT29	BS	[illegible]	[illegible]	NONE	75.00000	.
31	RCPT30	BS	[illegible]	[illegible]	NONE	75.00000	.
32	RCPT31	BS	[illegible]	[illegible]	NONE	75.00000	.
33	RCPT32	BS	[illegible]	[illegible]	NONE	75.00000	.
34	RCPT33	BS	[illegible]	[illegible]	NONE	75.00000	.
35	RCPT34	BS	[illegible]	[illegible]	NONE	75.00000	.
36	RCPT35	BS	[illegible]	[illegible]	NONE	75.00000	.
37	RCPT36	BS	[illegible]	[illegible]	NONE	75.00000	.
38	RCPT37	BS	[illegible]	[illegible]	NONE	75.00000	.
39	RCPT38	BS	[illegible]	[illegible]	NONE	75.00000	.
40	RCPT39	BS	[illegible]	[illegible]	NONE	75.00000	.
41	RCPT40	BS	[illegible]	[illegible]	NONE	75.00000	.
42	RCPT41	BS	[illegible]	[illegible]	NONE	75.00000	.
43	RCPT42	BS	[illegible]	[illegible]	NONE	75.00000	.
44	RCPT43	BS	[illegible]	[illegible]	NONE	75.00000	.
45	RCPT44	BS	[illegible]	[illegible]	NONE	75.00000	.
46	RCPT45	BS	[illegible]	[illegible]	NONE	75.00000	.
47	RCPT46	BS	[illegible]	[illegible]	NONE	75.00000	.
48	RCPT47	BS	[illegible]	[illegible]	NONE	75.00000	.
49	RCPT48	BS	[illegible]	[illegible]	NONE	75.00000	.

Fig. 8-3. Computed Receptor Concentrations Using Linear Programming Solution for Emission Density Zoning

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SECTION 2 - COLUMNS

NUMBER	.COLUMN.	AT	...ACTIVITY...	..INPUT COST..	..LOWER LIMIT.	..UPPER LIMIT.	.REDUCED COST.
238	EMDS1	BS	.74128	64.00000	.00170	NONE	.
239	EMDS2	BS	1.[illegible]	64.00000	.00178	NONE	.
240	EMDS3	BS	1.[illegible]	64.00000	.26260	NONE	.
241	EMDS4	BS	.[illegible]	64.00000	.00134	NONE	.
242	EMDS5	BS	.[illegible]	64.00000	.00036	NONE	.
243	EMDS6	LL	.[illegible]	16.00000	.01614	NONE	3.56552-
244	EMDS7	BS	.[illegible]	64.00000	.00182	NONE	.
245	EMDS8	BS	.[illegible]	64.00000	.00162	NONE	.
246	EMDS9	BS	.[illegible]	64.00000	.00184	NONE	.
247	EMDS10	BS	.[illegible]	64.00000	.00164	NONE	.
248	EMDS11	BS	1.[illegible]	4.00000	.00836	NONE	.
249	EMDS12	LL	.[illegible]	4.00000	.02211	NONE	2.27828-
250	EMDS13	LL	.[illegible]	4.00000	.02931	NONE	2.03328-
251	EMDS14	LL	.[illegible]	4.00000	.01567	NONE	.83802-
252	EMDS15	LL	.[illegible]	4.00000	.04986	NONE	1.83064-
253	EMDS16	LL	.[illegible]	4.00000	.04869	NONE	2.77510-
254	EMDS17	LL	.[illegible]	4.00000	.15737	NONE	1.94941-
255	EMDS18	BS	.[illegible]	64.00000	.00016	NONE	.
256	EMDS19	LL	.[illegible]	64.00000	.00142	NONE	1.76919-
257	EMDS20	LL	.[illegible]	64.00000	.00168	NONE	3.08497-
258	EMDS21	LL	.[illegible]	4.00000	.04931	NONE	1.50018-
259	EMDS22	LL	.05093	4.00000	.05093	NONE	1.15613-
260	EMDS23	LL	.04605	4.00000	.04605	NONE	.48343-
261	EMDS24	LL	.05008	4.00000	.05008	NONE	.10111-
262	EMDS25	LL	.20767	4.00000	.20767	NONE	.03703-
263	EMDS26	BS	1.[illegible]	4.00000	.06214	NONE	.
264	EMDS27	LL	.06022	4.00000	.06022	NONE	.03853-
265	EMDS28	BS	8.[illegible]	4.00000	.02630	NONE	.
266	EMDS29	LL	.[illegible]	6.00000	.02600	NONE	6.70357-
267	EMDS30	LL	.[illegible]	4.00000	.02945	NONE	1.67468-
268	EMDS31	LL	.[illegible]	4.00000	.01110	NONE	1.03441-
269	EMDS32	LL	.05047	4.00000	.05047	NONE	.45928-
270	EMDS33	LL	.[illegible]	4.00000	.05397	NONE	.12951-
271	EMDS34	LL	.[illegible]	4.00000	.18252	NONE	.24143-
272	EMDS35	LL	.[illegible]	4.00000	.05997	NONE	.36812-
273	EMDS36	LL	.06022	4.00000	.06022	NONE	.95310-
274	EMDS37	LL	.[illegible]	4.00000	.02540	NONE	1.07186-
275	EMDS38	LL	.[illegible]	4.00000	.03356	NONE	1.00775-
276	EMDS39	LL	.[illegible]	4.00000	.04477	NONE	.67728-
277	EMDS40	LL	.[illegible]	4.00000	.04786	NONE	.39535-
278	EMDS41	LL	.[illegible]	4.00000	.04841	NONE	.18477-
279	EMDS42	LL	.05923	4.00000	.05923	NONE	.46659-
280	EMDS43	LL	.05923	4.00000	.05923	NONE	.73463-
281	EMDS44	LL	.06022	4.00000	.06022	NONE	1.44490-
282	EMDS45	LL	.02540	4.00000	.02540	NONE	.48624-
283	EMDS46	LL	.[illegible]	16.00000	.00118	NONE	1.52406-
284	EMDS47	LL	.[illegible]	16.00000	.02603	NONE	2.05182-
285	EMDS48	LL	.[illegible]	16.00000	.03249	NONE	.16974-
286	EMDS49	LL	.03378	4.00000	.03378	NONE	.37072-

Fig. 8-4. Computed Emission Densities Using Linear Programming Solution for Emission Density Zoning

existing activity that was not to be retired. The maximum emissions were not specified, thereby allowing the highest emissions in any zone that would still be compatible with the NAAQS. Equation (8-5) was used for illustrative purposes only and is not intended to be a recommended condition. The first line of Fig. 8-3 gives the computed value of Eq. (8-5); that is, total regional emissions, at the maximum condition, are 1558 tons/day. The next 48 lines give the computed concentrations at 48 receptors. The column marked "Activity" gives the value of the computed concentration in $\mu g/m^3$. Note that none of the values exceed the primary annual NAAQS for particulates of 75 $\mu g/m^3$, which was chosen for this test case. Receptors 5, 19, and 20 are at their upper limit (UL) of 75 $\mu g/m^3$, while all others are below the limit (BS). The column "Slack Activity" indicates how far from the limit each receptor is. This figure illustrates that Eq. (8-3) is, indeed, being satisfied.

Figure 8-4 gives the solutions for the allowable emission densities (E_k in tons/km^2/day) for 49 of the areas. These are listed in the column "Activity." Note that a number of the emission densities are forced to their lower limit (LL) by the air quality constraints. These emission densities may form the basis of an air quality control plan. An agency may use these values to map out the areas most likely to absorb development without violating the NAAQS. Figure 8-5 gives a display of how the emission density pattern would be imposed on County X by this solution. Note that the higher emission densities are forced to the remoter areas of the county where there is currently least development. Many of the interior zones are pushed to their lower limit by the solution since there is already a significant amount of development thus precluding much of any increase. It is reemphasized that this is only an illustrative solution and should not be interpreted as the most desirable for the county. Additional options, such as other constraint formulations, would have to be investigated. Reference 49 contains some additional descriptions of emission density zoning.

Simplified Emission Density Calculations It is possible to arrive at an emission density type of control strategy without the use of a sophisticated linear program by using a simplified approach. Figure 8-6 outlines a method of approaching the problem. Assume that the emission densities computed for 7 of the zones in the region are given by those indicated on Fig. 8-6a. If this pattern results in projected violations of the NAAQS, then one

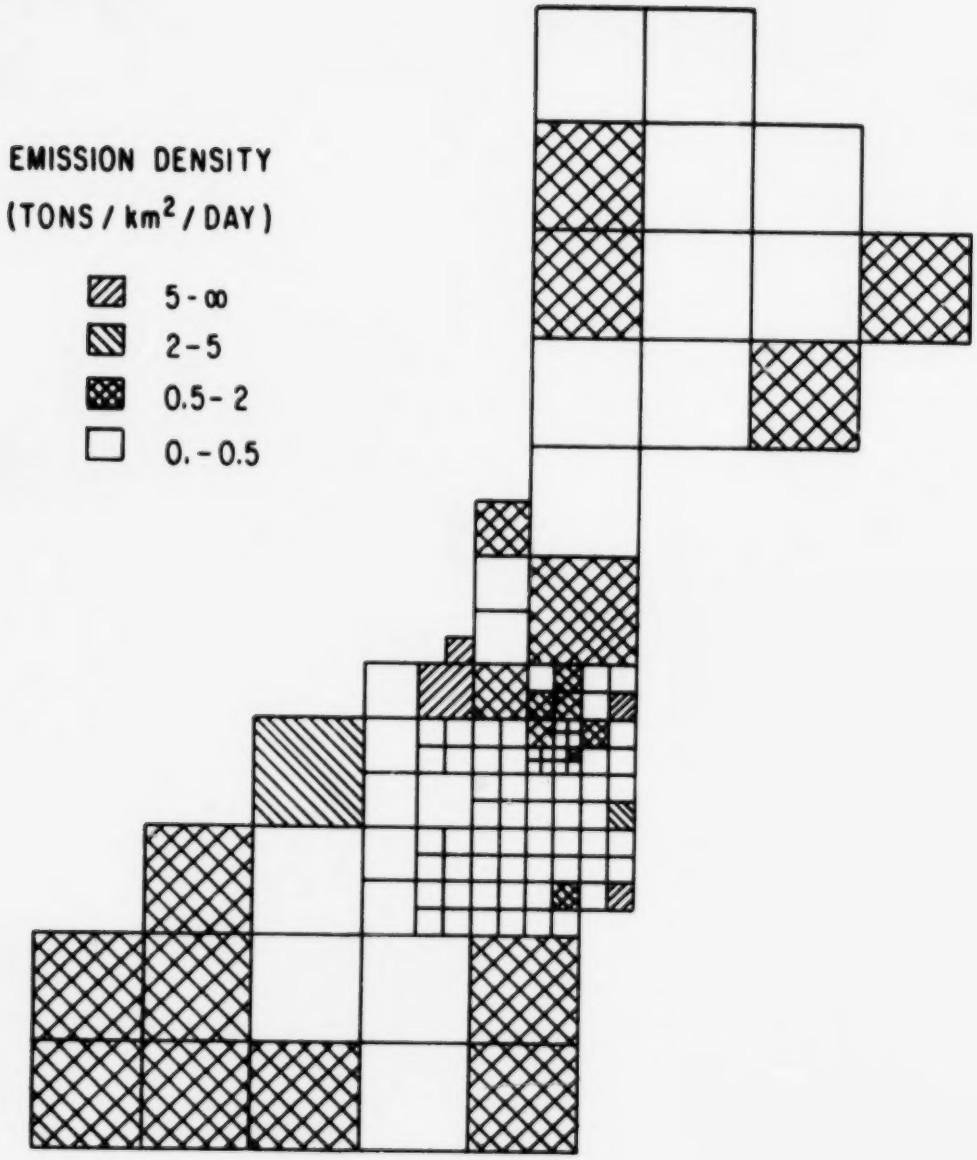

Fig. 8-5. Emission Density Zoning Solution Generated by Linear Programming

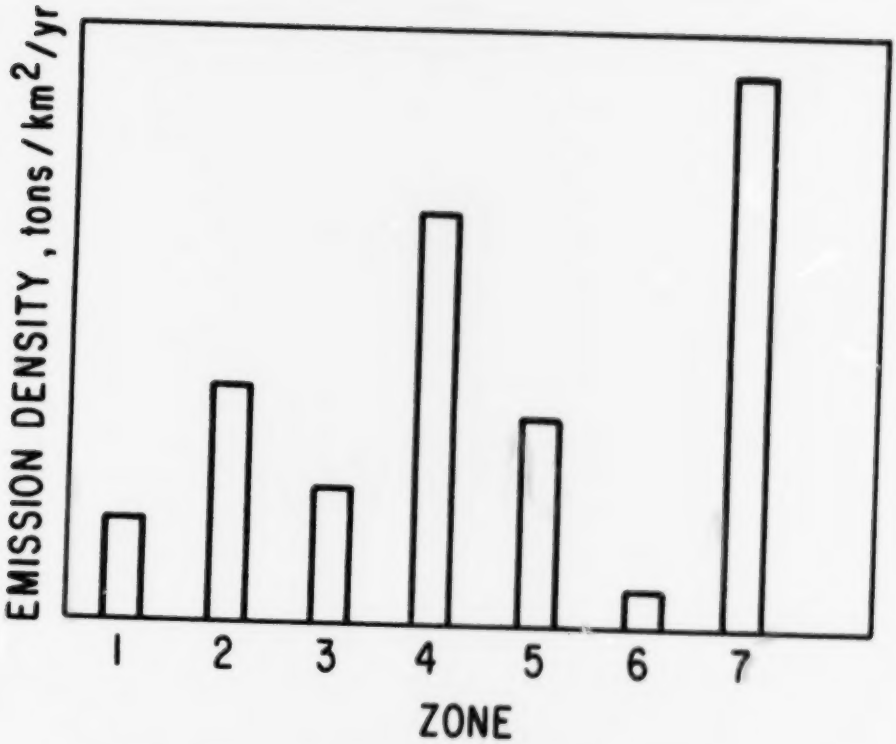

Fig. 8-6a. Existing Emission Densities

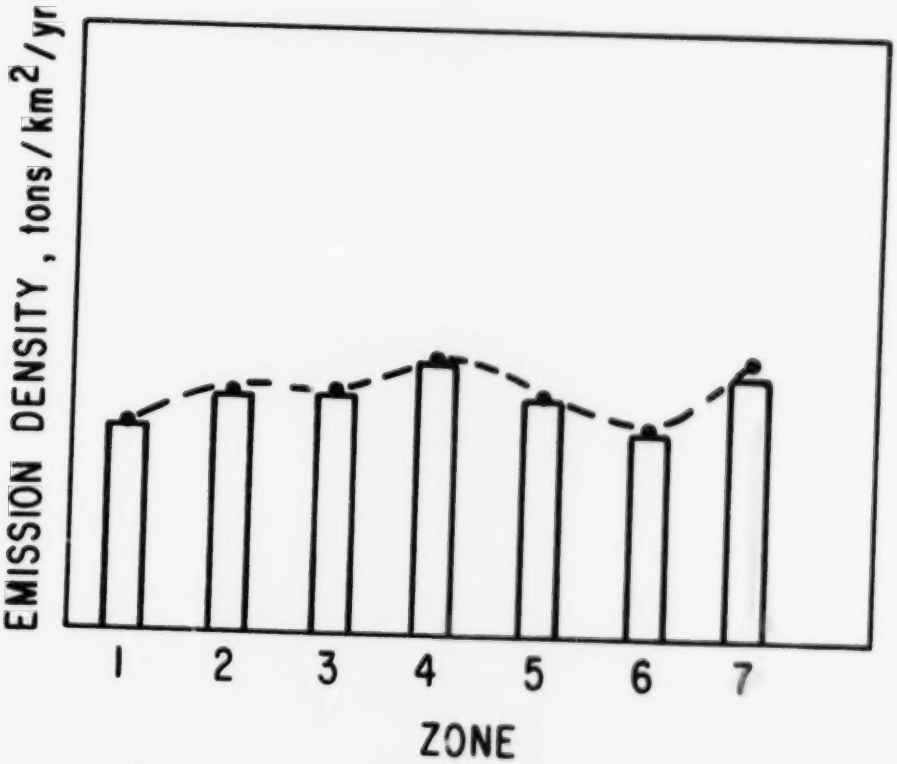

Fig. 8-6b. Adjusted Emission Densities

approach to developing acceptable emission density limits is to begin with the largest values (i.e., zones #4 and #7) and begin reducing these in a trial-and-error fashion until a level is reached that eliminates air quality violations caused by these sources. A dispersion model would have to be run to verify that the NAAQS are, indeed, being satisfied at these levels. With the maximum limits set, it may then be possible to allow increases in emission density from the other zones while still maintaining the NAAQS. Trial-and-error is again used to determine the limits and the final solution may look like Fig. 8-6b. Note that the emission density need not be uniform across the region.

This process will generate a solution to Eq. (8-3) since it is verified by trial-and-error application of a dispersion model. It may not, however, generate an optimum solution subject to other constraints. It is, however, a useful approach to use in evaluating whether a given development plan is compatible with air quality considerations.

Application of Implementation Instruments At this point there is a need to reemphasize the fact that there are a number of ways in which land use measures may be implemented in an air quality control program. Some of these are listed on Table 8-2. The techniques of emission quota and emission density zoning described here provide some analytical guidelines that can help in defining how far each of the implementation instruments must go in regulating development. For example, the computed emission quotas or emission densities may be incorporated directly into regulations using police powers for enforcement. Alternatively, the computed quotas or densities may serve as guidelines in establishing emission taxes with higher rates charged to sources locating in low-quota or low-density zones. The fact that needs to be realized is that there are analytical tools available to provide an interface between land use planning and air quality management. This can be exercised to develop a wide variety of control measures that can be justified, from a technical standpoint, as being compatible with air quality goals.

8.4 ILLUSTRATION OF COUNTY X RESULTS

Several strategies were applied to County X to determine their effectiveness in attaining and maintaining the NAAQS. Time and resources did not permit an evaluation of all possible options but the ones chosen illustrate several different approaches to control programs.

8.4.1 Increased Enforcement

The County X results displayed in Section 7 indicates that an attainment problem exists. However, some of the largest sources in the county are not in compliance with current regulations. A comparison of actual and allowable emissions in 1975 is included in Table 7-1. If increased enforcement of emissions regulations were to bring all the point sources in Table 7-1 to their allowable emission rates, the emissions would be reduced by 33,266 tons/yr, which is equivalent to 45% of the actual emissions.

Enforcement of the current regulations in 1975 will result in the air quality levels displayed in Fig. 8-7. Attainment of the NAAQS has been achieved in the isolated areas outside the central portion of the county where the 1975 isopleths displayed in Section 6 indicated violation of the primary standard. In the center of the county, the primary standard is still exceeded in a small area dominated by the largest stone quarry. Another small area where concentrations are only slightly above the secondary standard also exists near the central commercial area of the county. Although increased enforcement will bring air quality levels very near compliance over most of the county, complete attainment would not be achieved, and growth in successive time periods will still result in NAAQS maintenance problems. The conclusion is that some additional control program development is necessary.

8.4.2 Existing Source Retrofit to NSPS

One approach to solving the air quality maintenance problems in 1980 and 1985 is to require that all sources, existing facilities as well as new, be required to meet the lower emission factors of any applicable New Source Performance Standards implemented during the preceding analysis period. All production activity in stone quarries in the county, for example, would be required to meet an emission rate of 0.31 lb/ton of material processed in 1980, rather than the rate allowed in the county in 1975, which is 7.0 lb/ton. The effect on process emissions is contained in Table 8-3. Only two industrial process categories are of importance in the source inventory. Retrofit of all existing primary metals facilities would result in an emissions reduction for the industry of 30% in 1980 and 27% in 1985. Emission reductions from the mineral products industry with full retrofit in effect will be 90% of the base values in 1980 and 88% in 1985. With reductions of this magnitude in the

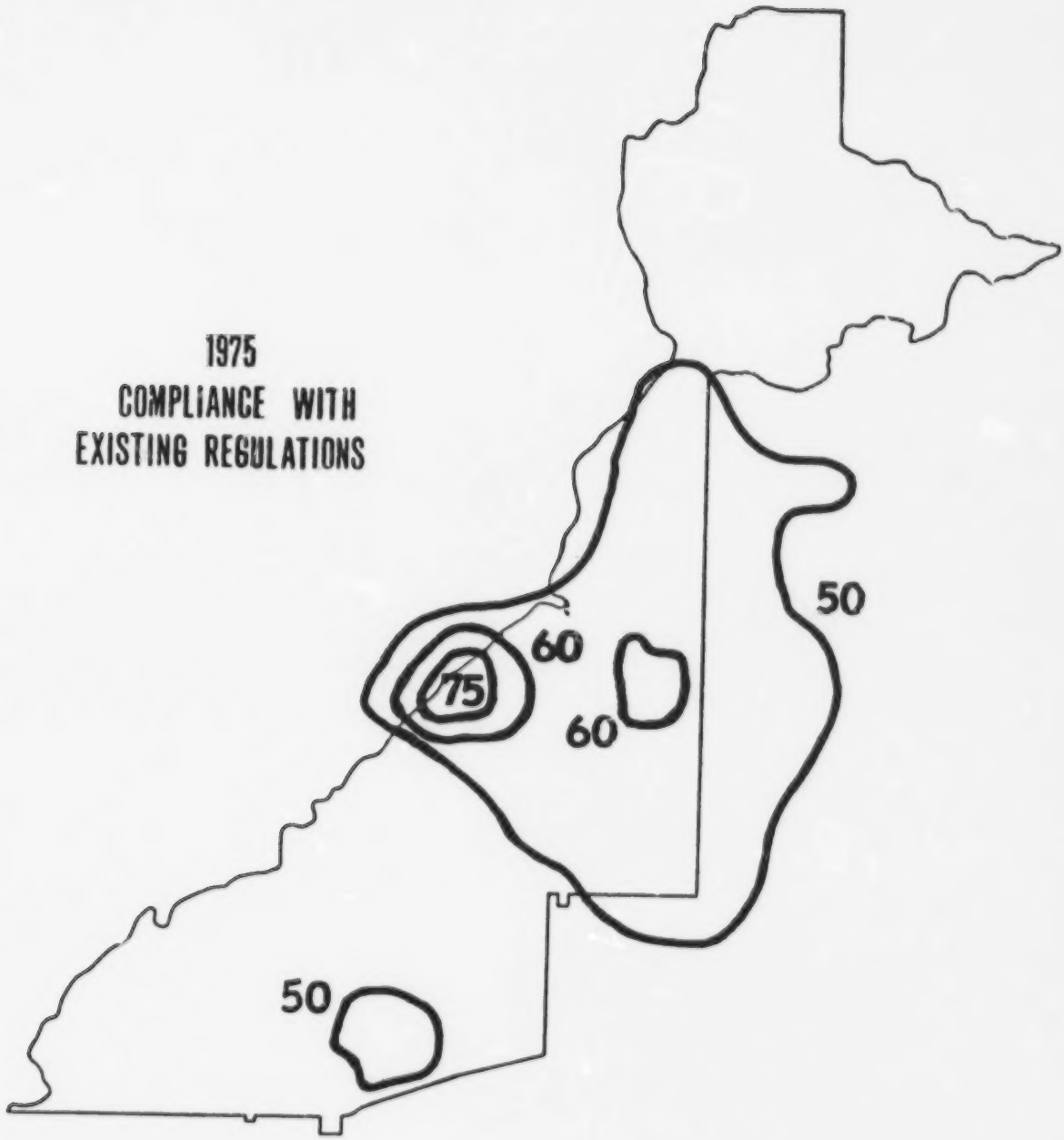

Fig. 8-7. County X Particulate Air Quality for Compliance with Existing Regulations in 1975

Table 8-3. Industrial Process Emissions for Retrofit of Existing Sources to NSPS

Source Category	1975	1980		1985	
	Emissions (T/yr)	Emissions (T/yr)	Emission Reduction over 1980 Base (T/yr)	Emissions (T/yr)	Emission Reduction over 1985 Base (T/yr)
Chemical Manufacture	1	2	0	2	0
Food/Agriculture	5	6	0	7	0
Primary Metals	9,720	9,219	3,975	10,928	3,972
Secondary Metals	41	18	38	24	39
Mineral Products	63,015	10,107	86,640	11,956	87,203

Table 8-4. Industrial Process Emissions for Selective Retrofit of Existing Sources to NSPS

Source Category	1975	1980		1985	
	Emissions (T/yr)	Emissions (T/yr)	Emission Reduction over 1980 Base (T/yr)	Emissions (T/yr)	Emission Reduction over 1985 Base (T/yr)
Chemical Manufacture	1	2	0	2	0
Food/Agriculture	5	6	0	7	0
Primary Metals	9,720	13,194	0	14,900	0
Secondary Metals	41	56	0	63	0
Mineral Products	63,015	41,097	55,650	43,342	55,817

dominant particulate emitting industry, dramatic improvement in air quality in the forecast years can be anticipated.

The modeling analysis of this strategy yields the air quality maps displayed in Figs. 8-8 and 8-9. In 1980 (Fig. 8-8) neither the primary nor the secondary standard is exceeded at any point in the county. Retrofit of all existing sources to NSPS emission rates is sufficient to attain and maintain until 1980 air quality below the NAAQS. Small areas in which the secondary standard is exceeded have begun to appear by 1985, however (Fig. 8-9). Hence, on a longer time frame, maintenance problems reappear even with the large emissions reductions that this strategy achieves.

Examination of the culpability list for the representative receptors reveals several of the uncontrolled and partially controlled large particulate emitting sources as leading contributors to the decline in air quality by 1985. In particular, the two steam plants that are uncontrolled and the two steel mills of which the largest particulate emitting operation remains uncontrolled contribute more than 25% of the calculated particulate concentration in the larger of the two areas above the secondary standard. Consideration of additional controls on emissions from these sources seems inevitable in succeeding review periods. The dominance of the stone quarries in determining the air quality in the county is largely broken by this strategy, but a stone quarry is still the largest single contributor to the smaller of the two areas above the secondary standard.

8.4.3 Selective Application of NSPS Retrofit

Across-the-board application of NSPS emission rates to existing sources might be very difficult or even impossible in some cases. Furthermore, blanket application of retrofit is probably not necessary in order to provide satisfactory management of air quality. By more closely examining the importance of individual sources to overall air quality, it should be possible to isolate a relatively small number of the existing sources whose specific control will give the desired results more effectively.

The list of major contributors to particulate concentrations at representative receptors in Table 7-1 provides a starting point in establishing a strategy of selective retrofit. Several of the source types in the table do not have New Source Performance Standards anticipated in this time frame,

Fig. 8-8. County X Particulate Air Quality for Full Retrofit Strategy in 1980

Fig. 8-9. County X Particulate Air Quality for Full Retrofit Strategy in 1985

and are therefore eliminated from further consideration under our assumption that retrofit will apply only to those sources for which NSPS have or will be promulgated. The steel mills (so far as their largest particulate emitting operation is concerned) and the steam plants are in this category. Interest is quickly focused on one of the brick plants and several of the stone quarries. An initial test of this strategy might involve only stone quarries 1, 2, 5, and 6, and the first brick plant. If the existing facilities at these five sources are retrofitted to NSPS, the industrial process emissions in the county will be as given in Table 8-4. Emissions are reduced only in the mineral products category, and the reductions are 58% of the base value in 1980 and 56% in 1985.

The modeling analysis of this selective application of NSPS retrofit to these five sources is displayed in Figs. 8-10 and 8-11. Concentrations at the five representative receptors remain below the primary standard through 1985. For two of them, however, the secondary standard is exceeded in both 1980 and 1985, and the extent of area involved is illustrated in the figures in which the two central areas in excess of 60 $\mu g/m^3$ increase between 1980 and 1985. To assure that the secondary standard is met and maintained over this analysis period using a selective retrofit strategy would require that the process be repeated, identifying additional sources as candidates for increased control. In general, such an analysis will reveal that source types not anticipated to be affected by NSPS regulations remain as the most important distinct contributors. In the larger of the two areas above 60 $\mu g/m^3$, for example, the uncontrolled steel mill operations and steam plants produce more than 20% of the total calculated concentrations. Rather than widespread application of NSPS to bring air quality levels down, a more effective strategy might be the selective retrofit as displayed combined with other controls that address the emissions from sources outside the expected NSPS regulations.

Violation of the primary standard around a point source in the southern part of the county remains unchecked. The representative receptor set chosen is only weakly sensitive to emissions from this source, and hence the procedure based on examination of the culpability list for the representative receptors failed to adequately gauge its importance. This oversight demonstrates the importance of judicious selection of receptors and of cross-checking with other information, such as the comparative magnitude of sources in the emissions inventory.

Fig. 8-10. County X Particulate Air Quality for Selective Retrofit Strategy in 1980

Fig. 8-11. County X Particulate Air Quality for Selective Retrofit Strategy in 1985

8.4.4 Emission Density Zoning

A technique that can be used to maximize allowed emissions while maintaining air quality at or below the NAAQS was described earlier. The solution was given in terms of emission densities in a set of zones that cover the county. To obtain a realistic solution, upper and lower emission density limits can be assigned to each cell reflecting both its existing state of development and the anticipated or desired future state. The inventory that has been generated in modeling the emissions within the county for 1975, 1980, and 1985 are strongly based on existing and likely future conditions in the county. They can form the basis for an heuristic approach to emission density zoning that will yield a possible, although not necessarily optimum, set of emission densities and density limits. This approach is essentially the simplified emission density zoning described in Section 8.3.2.

An inventory of emissions in the county for 1975, 1980, and 1985 was prepared in the form of area sources only, in which the emissions from a point source were added to the area emissions of the zone in which it occurs. Emission densities for the set of 121 zones covering the county show that most are relatively small. The zones with emission densities greater than 100 tons/km^2/year are displayed in Table 8-5; emissions from the zones in the table are about 107,000 tons/year in 1975, which is 15% of the county total. All but two of these high density zones are near the center of the county and are a combined result of a significant point source added to the area emissions of a relatively small zone. Three of the zones (88, 92, 97) show a decline in emission density between 1975 and 1980 in accord with anticipated phasing out of some industrial activity there.

The approach taken here in applying a strategy of emission density limits is to control only in the zones having highest densities. Several tentative upper density limits were chosen to explore the results that might be achieved. The limits tested were 3000, 1500, and 500 tons/km^2/year. The 3000 ton/km^2/year limit affects only two zones in 1980, and the 500 ton/km^2/year limit affects eight zones in 1985. With the lowest density limit, the emission reductions produced in these eight zones are listed in Table 8-6; although a small number of zones are affected, the emission reductions produced are sizeable portions of the initial inventory values.

Table 8-5. Calculated Emission Densities Under Base Conditions for 1975, 1980, and 1985

Grid[a] #	Emission Density, tons/km²/yr 1975	1980	1985
4	144.	163.	227.
25	101.	156.	173.
27	2436.	3695.	3740.
42	937.	1285.	1297.
63	1565.	2617.	2416.
73	84.	248.	272.
76	109.	117.	120.
77	3803.	3789.	3800.
82	2110.	2563.	3079.
83	115.	123.	127.
87	112.	117.	121.
88	136.	131.	132.
92	743.	613.	533.
97	2643.	2085.	2444.
100	3536.	4110.	4286.
105	287.	386.	389.

[a]All other grids have emission densities less than 100 tons/km²/yr.

Table 8-6. Required Emission Reduction to Attain 500 ton/km²/yr Zoning Regulation

Grid No.	Area (km²)	1980 Emission Reduction (T/yr)	1980 Emission Reduction (%)	1985 Emission Reduction (T/yr)	1985 Emission Reduction (%)
27	4	12780.	86	12958.	87
42	4	3140.	61	3187.	61
63	16	33865.	81	30659.	79
77	1	3289.	87	3300.	87
82	4	8252.	80	10317.	84
92	4	451.	18	134.	6
97	4	6339.	76	7776.	80
100	4	14438.	88	15146.	88

Modeling analysis of these three emission density limits applied to the 1985 inventory yields the results shown in Figs. 8-12, 8-13, and 8-14. As the emission density limit is lowered, progressively improved air quality is the result. At 3000 tons/km^2/year isolated very small areas with particulate concentrations in excess of the primary standard remain, and the secondary standard is still widely exceeded. Much reduced coverage of the area above the secondary standard is produced by the 1500 ton/km^2/year limit. The lowest emission density limit is sufficient to lower the air quality below both standards throughout the county. Through more detailed adjustment of the emission density limits, it would be possible to determine the limit just sufficient to assure that the standards are met.

The application of the strategy as displayed in these isopleths makes no assumptions about relocation of the emitting activity that would be restrained from locating in the affected zones. Study of the regional plan for the projected year should reveal locations appropriate for the displaced activities that will have low enough initial densities to be able to accept added growth without causing nearby air quality levels to go above the standards.

As was previously stated, the emission density computed to satisfy the air quality constraints (in this case 500 tons/km^2/yr) could become a direct regulation or could be used as a guide to developing other implementation instruments. For example, a zoning ordinance could be used to restrict the amount of industrial land in the affected grids. Alternatively, a regulation requiring buffer zones between industrial areas could be used. Certainly, new source review and permit programs could require demonstration that the density would not be exceeded for individual plants.

8.4.5 Floating Zone

The floating zone strategy was not evaluated in its fullest detail, but some review of its potential can be made. Figure 8-15 is a "footprint" of the air quality impact of a single plant with an emission rate of 100 tons/year and some representative stack parameters and was generated with the AQDM model. The asymmetrical shape of the isopleths is the result of the asymmetrical meteorology in County X. This type of footprint can be laid over any of the other displays to determine the areas where such a plant could locate without violating the NAAQS. To evaluate the effect of larger or smaller

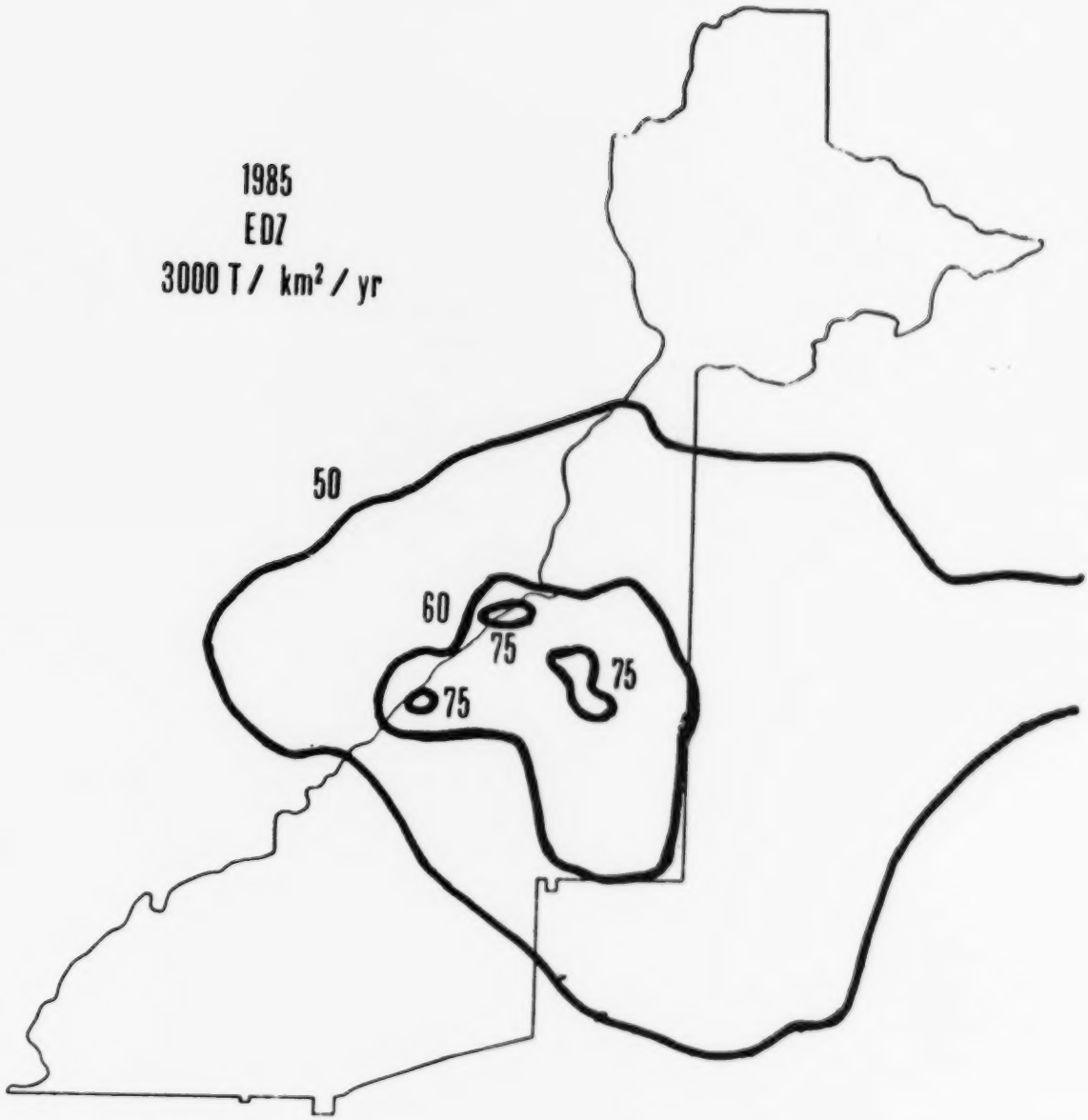

Fig. 8-12. County X Particulate Air Quality for Emission Density Zoning at 3000T/km^2/yr in 1985

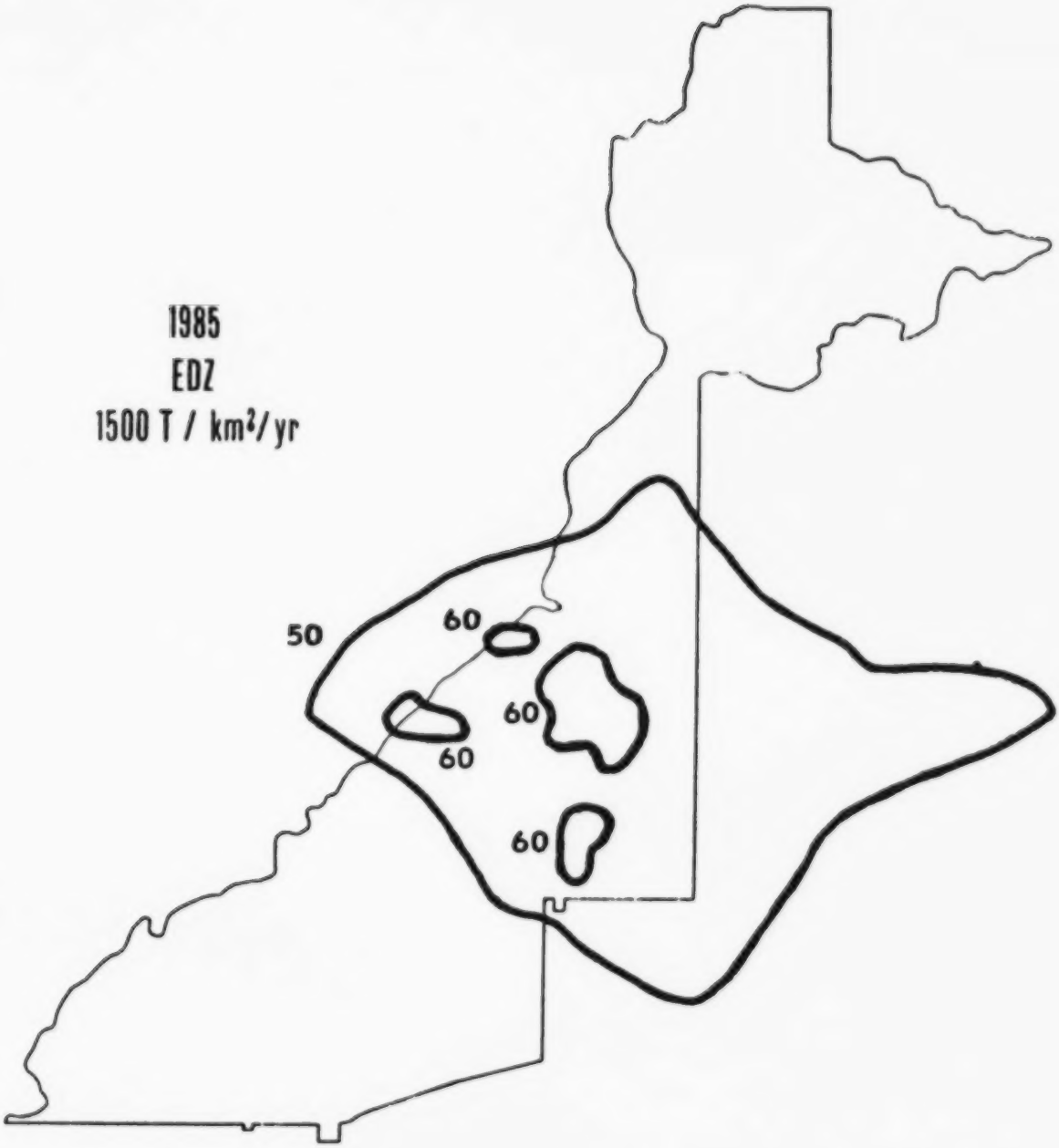

Fig. 8-13. County X Particulate Air Quality for Emission Density Zoning at 1500T/km^2/yr in 1985

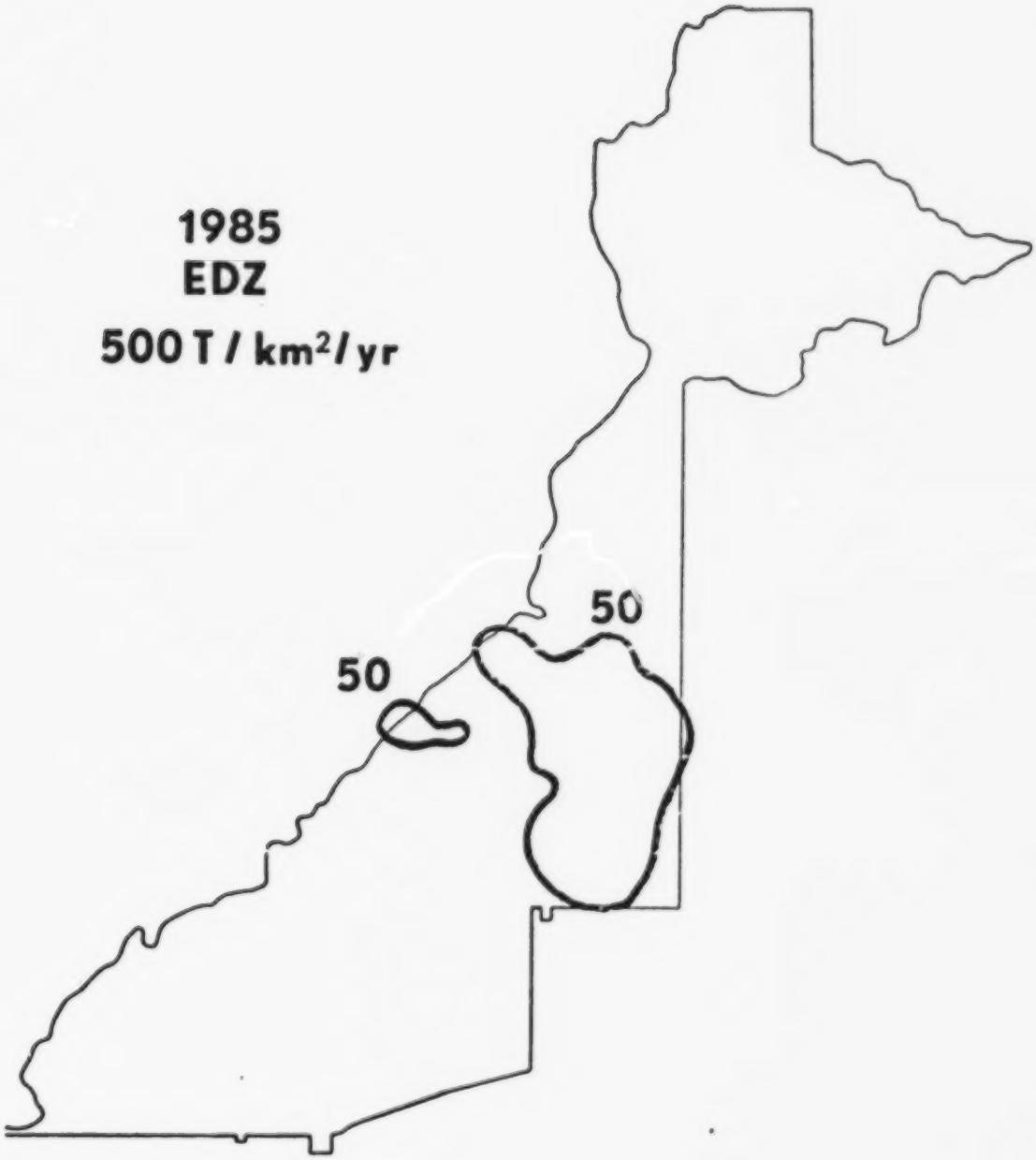

Fig. 8-14. County X Particulate Air Quality for Emission Density Zoning at 500 T/km^2/yr in 1985

Fig. 8-15. Air Quality Impact of a Single Source at 100T/day in County X

plants the isopleths may be scaled directly. One immediate application of this can be drawn from the emission density zoning strategy. This footprint can be used to help relocate facilities that have been zoned out of the high density areas.

8.4.6 Summary

To summarize the strategy analysis results, the following observations can be made:

> Existing control efforts will neither attain or maintain the NAAQS.
>
> Increased enforcement will marginally attain the NAAQS but will not result in air quality maintenance.
>
> Retrofit of existing sources to NSPS levels will attain and maintain the primary standards but will result in some secondary standard problems by 1985.
>
> Selective retrofit of only some existing sources will attain the primary standard throughout most of the county but not the secondary standard.
>
> Retrofit of existing sources, other than those to be covered by NSPS in the study time period, appears to offer some possibility for attainment and maintenance over the entire period.
>
> Emission density zoning to a level of 500 tons/km^2/yr will attain and maintain the standards throughout the time period.

These conclusions, though not comprehensive, illustrate the availability of control options for County X. Additional evaluations should be included to determine the effectiveness of combining several strategies as well as reviewing other alternatives.

9. STRATEGY SELECTION

At this stage of the Air Quality Analysis System a set of technically feasible control strategies has been developed for the study area; that is, a series of control measures which satisfy the constraint of attaining and maintaining the NAAQS has been developed. It now remains to select, from among these alternatives, the strategy or combination of strategies that will be most desirable for the study area. Hopefully, the screening process described in Section 8.2 will have already weeded out those control options that have little chance of being implemented due to known economic, social, or institutional constraints and the remaining options represent a realistic set of alternatives. These are many ways to approach the problem of strategy selection and one such framework will be described here.

9.1 OVERVIEW

Figure 9-1 gives an outline of how the strategy selection process might work. The starting point is the set of technically acceptable control options for which the analytical procedures have already been described (i.e., developing a baseline data set, projecting emissions, modeling, analyzing results, and strategy development and testing). The next step is to conduct an economic analysis to identify the relative costs of each control option. The concept of utility and a review of the differences between cost-benefit and cost-effectiveness analyses are necessary. Various types of cost computation procedures are available.

The third step is an institutional review and refinement of the control strategies through a coordinated evaluation procedure undertaken by all the participating agencies. The Delphi method is one means of arriving at a consensus of opinion.

The fourth step is a social impact analysis to identify the social consequences of the alternative control options. The use of qualitative assessments and the solicitation of public input into the review process are included in this stage. The Klee methodology is one tool that may be used to quantify some of the results.

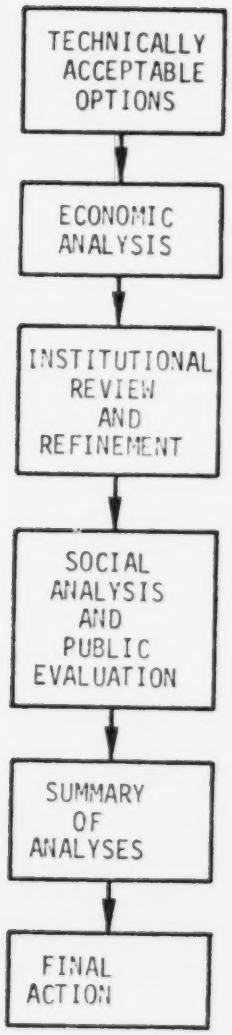

Fig. 9-1. Outline of Strategy Selection Process

The fifth step is a summary step. At this point the strategies have been subjected to technological, economic, institutional, and social analyses. In order for the analysis agency to get an overall perspective of the relative merits of each option, some form of summary presentation is necessary. The Washington Environmental Research Center (WERC) matrix is one form of presentation scheme, which satisfies many needs.

The final step is the selection of the preferred strategy or strategies and the submission of the plan through formal channels for review, required public hearings, and plan adoption.

9.2 ECONOMIC ANALYSIS

9.2.1 Concept of Utility

In evaluating economic values, the analyst is examining the individual's utility values. Utility can be defined as the value that each individual attaches to the various goods and services available. Generally, the market price is the quantitative measure of utility. An individual is willing to pay a given amount of dollars for a given amount of satisfaction. This satisfaction may be in the form of food, shelter, recreation, ownership of material goods, and others. In many cases, the utility cannot be measured quantitatively and subjective assessments are needed (e.g. aesthetics).

There is an elasticity in this utility, that is, if the market price of a good or service increases, the individual may still desire it enough to pay the higher price. There is, however, an upper limit beyond which price increases will cause the individual to decrease or stop his purchase of that good or service.

In an optimum situation, a society would try to achieve a condition wherein each individual had the maximum utility possible without subtracting from anyone else's utility. This is sometimes called Pareto optimality. In choosing among a variety of alternative directions to attain this optimum, the society must recognize that any one option may provoke a desirable response from all or part of the people, an undesirable response from all or part of the people, or an indifferent response from all or part of the people. In practice, the optimum state can never be reached; there is usually at least one individual who is not satisfied with the alternative (as opposed to being indifferent toward it). A non-optimum situation may still be desirable if

those who gain by it have enough of a gain to compensate those who lose by it and still have enough left over for themselves. Stating this "compensation principle" differently, if the monetary value of the benefits exceeds the monetary value of the costs, then the gainers can compensate the losers and still have some gains left over; the excess gains are the net benefits.

In the context of the evaluation of an air quality control strategy on the basis of economic costs, the analyst must recognize that the alternatives represent a cost (or utility) to various segments of society. The affected sources will have to pay a price to meet the control regulations in the form of control equipment, reduced productivity, and lower profits. If that price is too high, the source may decide that it is no longer worth it to stay in operation and may shut down. The consumers will have to bear the cost of control in the form of higher prices of goods and services, higher taxes to support enforcement activities, and some possible restrictions on their lifestyle. If that cost is too high there may be active opposition to implementation of the alternative. Public agencies will pay the price in the form of the need for more manpower and financial resources. If that price is too high the agency may have difficulty in securing the necessary funding from the legislature. All these must be considered when trying to arrive at the optimum selection of controls, which in this case would be least cost to all parties involved.

When forced into a non-optimum situation, that is, the selected strategy would require one sector to bear a higher cost, then it may be necessary to justify this to them by demonstrating that this strategy would provide some overall net benefits which will outweigh the increased cost.

9.2.2 Cost-Benefit vs. Cost-Effectiveness vs. Least Cost

In conducting economic analyses the three most widely used techniques are cost-benefit analysis, cost-effectiveness analysis, and least cost analysis. A cost-benefit analysis relies on the compensation principle previously described. In doing the analysis, one estimates the economic costs of a particular alternative and compares them to the economic benefits. The strategy with the lowest cost-benefit ratio is the most desirable, all other things being equal (e.g., political constraints, etc.). Strategies with a cost-benefit ratio

greater than 1.0 are rejected as being economically infeasible. Unfortunately, as simple as it sounds, a cost-benefit analysis is very difficult to conduct if it is to be done properly. There are numerous factors which defy precise quantification and the list of costs and benefits to be included for evaluation is subject to wide variations in interpretation. Cost-benefit analyses are generally aimed at comparing multiple objectives or programs to determine how a limited resource should be spent.[50] The one which provides the most benefits at the lowest cost (i.e., the lowest cost-benefit ratio) is desired. In the air quality analysis case, there is only one objective, that is, attainment and maintenance of the NAAQS, and a cost-benefit analysis, in its purest sense, would not be directly applicable.

An alternative approach is the use of a cost-effectiveness evaluation. This method is aimed at maximizing a single objective using scaled cost-effectiveness ratios. In an air quality context, this type of analysis would be applied to determining how much air quality improvement (concentration reduction) would result from a given expenditure of money. A typical cost-effective ratio would be measured in dollars per $\mu g/m^3$ of concentration reduction. In using this approach, the analyst must realize that the NAAQS (i.e. the single objective) must be met even though it may not be met in an optimum way.

The third approach is to use a least cost evaluation in which the option with the lowest total cost is the most attractive. This is the simplest of the three to use.

9.2.3 Cost Parameters

Whether cost-benefit, cost-effectiveness, or just least cost computations are used, there are some procedures that are common to all.

Costs to be Considered Direct and indirect costs will result from the implementation of a strategy, and the costs will be borne by both the private and public sectors. Table 9-1 is a list of the control strategies evaluated for County X along with corresponding cost elements that might be considered in applying an economic analysis to the strategies. Direct costs to the regulated sources and the control agency are relatively evident. Depending on the strategy under analysis, both might have expenditures related to planning and design; to land, building, and equipment purchase or rental; to operations and maintenance of buildings and equipment; to training of personnel in new

Table 9-1. Cost Elements Involved in County X Strategies

Strategy \ Cost Elements	Public Agency and Business Costs									Public Agency Costs			Business Costs		Indirect Costs			
	Program Planning	Facility and System Design	Purchase or rental of land & buildings	Purchase or rental of equipment	Financing Costs	Equipment Operation	Equipment Maintenance and Repair	Training of operators, supervisors, and clerical	Wages of personnel required by Strategy	Interagency Cooperation	Surveillance and Record Verification	Additional modeling and monitoring specific to strategy	Additional Industry Location Costs	Capital loss due to premature obsolescence	Profit loss for firm not directly affected	Indirect effects on resources and prod. prices	Change in public expend. from capital revenue	Increased fees and tax payments
New Source Performance Standards	X	X	X	X	X	X	X	X		X	X			X	X	X		X
Retrofit	X	X	X	X	X	X	X	X	X								X	X
Selective Retrofit	X	X	X	X	X	X	X	X	X								X	X
Phaseout	X	X	X	X	X	X	X	X	X	X	X		X	X	X			X
Emission Density Zoning	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	
Floating Zone	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	
Fugitive Dust Control		X		X	X	X	X	X	X			X	X			X		

responsibilities; and to wages paid to additional personnel. Differences among the strategies could be important due to additional control agency expenditures for interagency coordination activities, surveillance and record verification, and strategy-specific modeling and monitoring. Similarly, distinct additional direct costs that might be borne by the regulated sources include suboptimal location of industry and capital loss due to premature obsolescence. Most of the direct costs can be estimated with considerable accuracy in terms of monetary value and timing.

Indirect costs are more difficult to trace. Some examples of indirect costs are loss of profits for firms not directly affected by a strategy, effects on resources and product prices, changes in public expenditures from general revenues and increases in fees and tax payments. Evaluation of secondary and, to an even greater degree, tertiary costs are much more subjective than is true of direct costs. Perhaps the most effective way of addressing these indirect costs is through the techniques for determining the opinions of decision makers and members of the general public that are discussed in other parts of this section. This might be especially important if the distributed aspects of the indirect costs (i.e. who will bear what portion of the indirect costs) are to be satisfactorily considered.

Present Value Calculations In the analysis of future expenditures, the effects of inflation and the present value of future expenditures should be considered. The present value concept is based on the fact that a smaller number of current dollars, invested at some interest rate, would be equivalent to a required future capital expenditure. That is, C current collars invested at an annual interest rate i would yield $C(1 + i)^t$ dollars t years in the future. Conversely, if an expenditure E will be required t years in the future, its discounted current value, assuming an interest rate i, would therefore be $E(1 + i)^t$, based on $E = C(1 + E)^t$.

For yearly operating costs Q (in constant value dollars) continuing over a period of t years, a similar analysis discounting each year's costs to the present and summing the present value costs for all t years, can be carried out. The same result is obtained by multiplying the annual expenditure by a single factor $[1 - (1 + i)^{-t}]/i$. The key equations in present value calculations are:

$$\text{Present Value \$} = \text{Cost \$} \times (1 + i)^{-t} \quad \text{for capital costs} \qquad (9\text{-}1)$$

$$\text{Present Value \$} = \text{Annual Cost \$} \times \frac{1-(1 + i)^{-t}}{i} \quad \text{for annual costs} \qquad (9\text{-}2)$$

where i is the interest rate and t is the number of years.

Correction for Inflation The discounted present value calculations of future expenditures should be carried out with constant value dollars. This is equivalent to factoring out the effects of inflation. If the current value of a dollar is chosen as the standard and an inflation rate e is assumed, an expenditure E made t years in the future would have a value of $E(1 + e)^{-t}$ in terms of constant value dollars. The combined effects of accounting for inflation and discounting future expenditures to present value is that a future expenditure would be valued only at $E[(1 + i)(1 + e)]^{-t}$ at the present.

The key equations become:

$$\text{Present Value in Constant Dollars} = \text{Cost \$} \times [(1+i)(1+e)]^{-t} \quad \text{for capital costs} \qquad (9\text{-}3)$$

$$\text{Present Value in Constant Dollars} = \text{Annual Cost \$} \times \left[1 - \frac{[(1+i)(1+e)]^{-t}}{(1+i)(1+e)-1}\right] \quad \text{for annual costs} \qquad (9\text{-}4)$$

PROBLEM 9-1

Determine the present value cost in constant dollars of two control strategies based on the following information:

Alternative 1:	Capital cost $1 million in years 1, 5, 20 Operating cost $10 thousand per year
Alternative 2:	Capital cost $0.5 million in year 1 1.0 million in year 10 2.0 million in year 20 Operating cost $50 thousand per year

Assume an inflation rate of 6% per year. Which alternative is economically most attractive at a 7% interest rate and at a 10% interest rate?

9.3 INSTITUTIONAL REVIEW AND REFINEMENT

Although not explicitly treated in this review, a substantial requirement for interagency cooperation and coordination exists for the development of an adequate air quality management plan and has been alluded to in various sections. The agency conducting the analysis must realize that the strategies being considered may impact heavily on the programs of other agencies and it is essential that all of the affected groups have an opportunity to review the alternatives and participate in strategy selection. Eventually, the proposed air quality management plan will be subjected to an intergovernmental and interagency review under the guidelines of Circular A-95 of the Office of Management and Budget (OMB). If the agencies participating in the A-95 review have not had prior opportunity to input their viewpoints into the strategy selection process, then serious delays could occur in the clearing of a proposed air quality management program and adoption of a plan. Therefore, it appears desirable to provide for some form of institutional review of the available control strategies prior to the selection of the preferred strategy(ies) and submission for formal A-95 clearance. This stage (i.e., after the economic evaluations are available) is an ideal time to implement this kind of review since the particpating agencies will have a great deal of the technical and economic data available from the previous analyses. First, a brief discussion of the A-95 review process will be presented to give a perspective on what will eventually be required in a formal way and then some methods of obtaining an interagency opinion and consensus in this informal review will be outlined.

9.3.1 A-95 Review Requirements

The A-95 review process provides a structure for multifunctional planning by strengthening the communication among agencies and different governmental levels. It has four basic parts: (1) state and areawide review of federal aid applications to avoid conflicting programs, (2) federal agency consultation with state and local governments prior to undertaking direct federal development projects, (3) gubernatorial review of federally required state functional plans before submission for federal funding, and (4) coordination of federally supported planning programs at the sub-state regional level.

Of the four parts, one and four are the most important in terms of interagency coordination. The Project Notification and Review System (PNRS) has been established under part one. PNRS designates state regional/metropolitan planning agencies as clearing houses, many times these are Councils of Government (COG's). It is the responsibility of these clearinghouses to identify appropriate state and local environmental agencies and to make them aware of a proposed project for which a federal grant is being requested and on which they should have an input.

Part four of A-95 review requires coordination of federally supported programs at the regional level. Utilization of an A-95 agency for areawide planning instead of separate regional agencies improves coordination of different plans and makes for efficient integration of them into a consistent regional comprehensive plan. In seeking federal grants, general purpose planning agencies are given preference over single purpose agencies.

The A-95 clearinghouse can be used to identify those agencies that should be involved in this institutional review. The group should be made up of, at a minimum, representatives of all agencies that will eventually participate in the formal A-95 review process. Other groups may be invited as necessary.

9.3.2 Developing Group Consensus

There are many ways to arrive at a group decision as to the acceptability of the various control alternatives. One formal and structured method of review involves implementation of the Delphi methodology, possibly in conjunction with conferences or committee meetings. The Delphi methodology is a technique that was developed, principally by the Rand Corporation, to utilize, systematically and to the maximum advantage, the subjective judgments of experts.[51] The exact procedure has never been fixed, thereby allowing for flexibility to the circumstances and degree of judgment.

The chief characteristic of the Delphi methodology is its iterative structure. A Delphi is conducted in a series of rounds, and in each round every participating 'expert' works through a questionnaire. The questionnaires also include room for comments, allowing any 'extremists' to state the reasons for their stands. The questionnaires are returned to the organizer, who in turn edits the answers and comments. The editing phase is a crucial step, for the

efficiency with which added information is shared among participants is a function of the method by which feedback is organized.

A summary statement and new questionnaire (generally abbreviated form of the previous questionnaire) are then returned to the participants. In this manner, participants are made aware of the various reasons underlying the spread of opinion. Generally, the summary statement takes the form of a mean or median and some measure of opinion dispersion of each question such as the interquartile range. As mentioned above, the summary statement also includes a summary of the comments.

The general components of the Delphi are:

The user, i.e. the person or persons who intend to utilize the information generated from the Delphi,

The respondent group, i.e. the 'experts,' and

The organizer or design team.

There are some general observations to be made with respect to Delphis. These include:

1. The number of professionals required for the design team varies from two to five in direct proportion to a respondent group of 10-50.

2. The number of clerical people should equal the number of professional people.

3. If the Delphi is conducted by mail, the respondent should be allowed three or four days to respond, and each round should be analyzed in one or two weeks with allowance for overtime.

4. The design team should prepare a fact and data summary indicating whatever appropriate benefit or cost measures are available on a historical basis.

5. If there is a trade-off between the ease of summarizing the results and the ease of the respondent in providing the answers, the choice should always favor the respondent since he might refuse to do the work if it becomes too demanding.

By conducting a Delphi in conjunction with conferences or committee meetings, many of the disadvantages of each are eliminated. The purpose of the Delphi at this point of strategy selection is not so much to obtain a consensus on one strategy as it is to establish the various positions on a number of strategies.

One of the greatest assets of the Delphi methodology is its stimulating approach. Flexibility in design, elimination of inter-personal conflicts, and equal weighting of opinions are all positive aspects of the Delphi methodology.

Questionnaire length, difficulty of the questions, and time allocation are all areas that should be closely examined by the design team. A single long session may become an inconvenient expense of time for the 'experts' involved, who may therefore be discouraged from participating initially. On the other hand, an extended Delphi, whether organized by mail or other means, is subject to the inevitable delays in the return of responses to each round. Therefore, from the organizational standpoint, the timing and scheduling of a Delphi may be one of the most important elements of its design.

An alternative to the use of a Delphi is committee meetings where the economic analyses are presented and the implications discussed orally; a final vote is then taken and the strategies are either eliminated or accepted for further analysis. One disadvantage of this method is that the most vocal or strong-willed participants are likely to have an overriding influence on the group's decision.

9.4 SOCIAL ANALYSIS AND PUBLIC EVALUATION

In addition to the technological, economic, and institutional analyses required for the selection of strategies for an air quality control program, it is necessary to review the potential social impacts and to obtain public input and comment on the acceptability of the various options. These studies are focused on determining the indirect and qualitative "costs" of the strategies.

9.4.1 Public Comment and Assessment

Formal public hearings are required prior to the adoption of any air pollution control regulations.[14] In a manner analogous to the A-95 review, it may be desirable to obtain a sampling of public opinion prior to the formal hearings to avoid delays resulting from an oversight on public reaction. Depending on available time and resources, public input may be obtained through:

Media publicity soliciting comments,

General surveys either by mail, phone, or door-to-door, or

Public meetings to discuss the options.

The purpose of these procedures is to inform the public of the strategies being considered and the implications of each, and to provide another basis for selecting strategies.

9.4.2 Social Analysis

Information received from the public comments can be used to develop a formal social analysis that assigns a relative ranking to each of the possible social impacts associated with the various strategies. This may be done internally by the agency performing the air quality analysis or externally using a Delphi process similar to the one described for the institutional review.

A quantitative methodology developed by A. J. Klee[2] might be useful to structure the analysis. In this case the air quality planning agency conducts the analysis of the relative social impacts of the strategies. There are six basic steps. These include:

1. Planning agency chooses the social analysis factors it feels are important (see Table 9-2). Insofar as possible, these factors should be mutually exclusive to avoid overemphasis.

2. The importance of these social factors is determined by listing them in some arbitrary manner on Table 9-3. The order should not effect the final rating. Fill in the R_i column of Table 9-3 as follows. Next to the first factor, fill in R_1 = relative importance of factor (1) : relative importance of factor (2). Continue following this procedure to obtain the relative importance of R_i compared to $R_i + 1$. The K_i column is now filled in by starting at the bottom of the column and entering 1.0. The next to last row will have $K_{n-1} = K_n \times R_{n-1} = R_{n-1}$. The second to last row is obtained by multiplying K_{n-1} times R_{n-2}. Upon entering K_1, sum all the K_i's to yield K. Each K_i is the relative importance of the ith factor compared to all other factors. For factors of four or less, it is felt the R_i column can be abandoned. Thirdly, fill in the W_i column. This is accomplished by simply dividing the corresponding K_i by K. The sum of the W_i's should equal 1.0.

3. This step is simply a consistency check on Table 9-3, and can be accomplished by using Table 9-4. Enter the factors in the order of their computed W_i's in descending order. The C_i column is obtained by starting at

Table 9-2. Examples of Social Factors

Sector	Factor
Transportation	Ease of Access to: – places of employment – educational, cultural and historical features – recreational facilities – commercial (shopping) areas Equitable distribution of cost
Population	Size Distribution Density Mobility
Institutional Relationships	Maintenance of traditional political authority Maintenance of the informal community structure
Employment	Mobility Growth Distribution
Quality of Life	Change in air quality Change in water quality or supply Loss of open space Impact on ecologically critical areas Impact on regional noise levels

Table 9-3. Derivation of W_i in Klee Methodology

Social Factor	R_i	K_i	W_i
Factor 1	R_1	K_1	$K_1 \div K$
Factor 2	R_2	K_2	$K_2 \div K$
Factor 3	R_3	K_3	$K_3 \div K$
.	.	.	.
.	.	.	.
.	.	.	.
Factor n-1	R_{n-1}	K_{n-1}	$K_{n-1} \div K$
Factor n	---	1.0	$1.0 \div K$
Total		K	1.0

Table 9-4. Consistency Check

Ordered Social Factor	W_i	C_i
Factor 1	W_1	C_1
Factor 2	W_2	C_2
Factor 3	W_3	C_3
.	.	.
.	.	.
.	.	.
Factor n-1	W_{n-1}	C_{n-1}
Factor n	W_n	----

bottom of the column in the next-to-last row, where $C_{n-1} = W_n$. Next $C_{n-2} = C_{n-1} + W_{n-1}$. In general, $C_i = C_{i+1} + W_{i+1}$. The consistency check then asks the planning agency to compare a factor with all of the factors appearing below it. Suppose $W_1 > C_1$, then it should be the opinion of the planners that factor 1 is more important than all the other factors combined.

4. Calculate the subscores of the maintenance strategies for each social factor. If it is decided that a strategy will have different effects depending on the time it is implemented, calculations for these time periods should be made. For factor 1, the local planning agency should decide the relative importance of the effect of each of the strategies. The R_j column is filled in a manner similar to the R_i column, where R_1 = (importance of effect of strategy (1) : importance of effect of strategy (2). Next the K_j column is computed by setting $K_m = 1.0$ and then $K_{m-1} = K_m \cdot R_{m-1}$. After all K_j's have been computed, sum them to find K. Finally compute S_{ij} by dividing each K_j by K. This process is then duplicated for each factor.

5. The subscores are combined with the factor weights to determine the overall social effect of each alternative strategy. This should be done for each time period. Enter the proper weighting factor (W_i) in each column of Table 9-5 and then enter the appropriate subscores in the product of the W_i entry with the S_{ij} entry.

6. Next, the evaluations A_j are found by summing the product columns across each row. Enter the evaluation scores from Table 9-5 into the appropriate columns in Table 9-6, and then compute the average evaluation score for each strategy. Finally, rank the strategies by assigning the highest rank (i.e., 1) to the strategy with the largest average evaluation, etc. Averaging evaluation scores implies that social impact occuring in the future is as important as impacts occurring at the present time. Due to uncertainty about the future, the planning agency may feel that immediate consequences are more important than long term. In this case, a careful examination of the evaluation through time should be made.

Table 9-5. Computation of Evaluation Scores

Time Period: from ___ to ___							
Maintenance Strategies	Social Factor 1...			Social Factor N			Evaluation Scores (A_j)
	W_1	S_{ij}	Prod.	W_n	S_{nj}	Prod.	
Strategy 1	W_1	S_{11}	$W_1 \times S_{11}$	W_n	S_{n1}	$W_n \times S_{n1}$	A_1
Strategy 2	W_1	S_{12}	$W_2 \times S_{12}$	W_n	S_{n2}	$W_n \times S_{n2}$	A_2
.		.			.		.
.		.			.		.
.		.			.		.
Strategy 3	W_1	S_{1m}	$W_1 \times S_{1m}$	W_n	S_{nm}	$W_n \times S_{nm}$	A_m

Table 9-6. Summary, Ranking of Evaluation Scores

Maintenance Strategies	Evaluation Scores from ___ to ___	from ___ to ___	Average Evaluation Score	Rank
Strategy 1	A_1	A_1	Avg. 1	
Strategy 2	A_2	A_2	Avg. 2	
Strategy 3	A_3	A_3	Avg. 3	
.	.	.	.	
.	.	.	.	
Strategy M	A_m	A_m	Avg. m	

9.5 SUMMARY AND REASSESSMENT OF STRATEGIES

It is now desirable to summarize all the available information on the various strategies and to select a preferred strategy(ies). The Washington Environmental Research Center (WERC) matrix is one possible means of displaying this information. The WERC matrix is an adaptation of the Residuals-Environmental Quality Management framework. A suggested WERC matrix is illustrated in Table 9-7.

The first column of the WERC matrix contains the strategies as described earlier. The second column contains the implementation tools. Implementation tools are the methods by which the strategies are employed. Examples of implementation tools include zoning and emission rates for emission density zoning, schedules for phaseout, inspection programs for fugitive dust control, taxes, compliance schedules, and economic incentives, and permit programs.

The third column contains the present effectiveness of the specific strategy and is the percent reduction in total emissions from the source category expected from the strategy. This figure should be obtainable at the technological analysis phase. The fourth column, emission reduction, is obtained as the product of the effectiveness times the source category (SIC codes) contribution to the total concentration.

The fifth column contains economic considerations under the headings of: Direct Costs, Administrative Costs and Social Costs. Direct costs to the polluter include the costs of any measures needed to comply with the strategy. Direct costs to the consumer are the increased prices of the polluter's product as a result of abatement. Direct costs to the government are out-of-pocket costs such as subsidies to assist the source in complying.

The administrative costs are indirect costs of program management, enforcement, monitoring, etc., paid by public funds for the institution and maintenance of specific solution abatement strategies.

Social costs are the costs that indirectly manifest themselves as having a negative impact on area income, employment, regional prices or some other measure of community well being.

Table 9-7. Washington Environmental Research Center (WERC) Matrix

	Implementation Tool	% Effectiveness	% Reduction	ECONOMIC CONSIDERATIONS 1 - Most Expensive 2 - Moderately Expensive 3 - Least Expensive												Social Responsiveness					Administrative Considerations					
				Direct Costs				Admin. Costs				Social Costs									Control Application					
				To Polluter	To Consumer	To Government	Other	Program Mgmt.	Enforcement	Monitoring	Other	Area Income	Area Employment	Regional Prices	Other	Most Acceptable	.	.	.	Least Acceptable	Flex. 1-Most 2. - 3-Least	Legal Precedent Exists Y-yes N-No	Continuous	Noncontinuous	Selective	Uniform
Strategy 1																										
Strategy 2																										
Strategy 3																										

The sixth column is Social Responsiveness, and reflects the results of the social analysis phase.

The final column contains the administrative considerations. Flexibility is the ability of the specific strategy to respond and adopt to changing conditions and/or objectives over time.

This matrix can provide a means of summarizing the information and proceeding to select the preferred strategy. The Delphi process or open committee meeting may again be used to arrive at a consensus.

9.6 FINAL ACTION

Upon completion of the review and selection of preferred strategies the plan is now ready for processing through the formal A-95 review, public hearings and submission to EPA as part of the State Implementation Plan. If the analysis has been carefully executed there should be no need to expect major revisions or disapproval.

APPENDIX A
AIR QUALITY DATA FORMATS AVAILABLE FROM SAROAD

Examples of the seven SAROAD formats most likely to be useful in an attainment/maintenance analysis are given in this appendix. A short description of each format and the various retrieval options follows:

Figure A-1. Yearly Frequency Distribution. This report gives a frequency distribution by year and pollutant with site description. The arithmetic average or geometric mean is given for data satisfying summary criteria. The report can be selected by the following keys:

Pollutant,
State,
State/Area,
State/Area/Site,
Year,
AQCR,
Pollutant/Interval,
Pollutant/Method,
Any combination of the above.

Figure A-2. Quarterly Frequency Distribution. This report gives the same information as the yearly frequency distribution but on a quarterly basis and may be retrieved by the same keys.

Figure A-3. Yearly Report by Quarters. This report gives the site description and following data items:

Possible % of observations,
Arithmetic average and standard deviation,
Minimum & maximum observation,
Number of observations and arithmetic average by quarter.

Figure A-4. Inventory by Site. This report gives the pollutants monitored at each site by year and number of observations, maximum observation, and arithmetic mean by year. The report can be selected by state or for the nation.

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Figure A-5. Inventory by Pollutant within State. This report gives all sites and years of data within a state for any given pollutant. The number of observations, maximum observation, and arithmetic mean are also given for each pollutant and year. The report can be selected by pollutant and state.

Figure A-6. SAROAD Listing for Raw Data Greater than 24-Hour Average. This report lists the raw data for 24-hour or longer observations or for composite data with a page break when the pollutant changes. This report can be retrieved by the following keys:

Pollutant,
State,
State/Area,
State/Area/Site,
Year,
Pollutant/Method,
Any combination of the above.

Figure A-7. Standards Listing. This report gives a report as shown for each standard which has been set. The observations are converted to standard reporting units and observations exceeding the standards are marked. The reports are retrieved by the following keys:

State,
AQCR,
Pollutant,
Year,
Any combination of the above.

NATIONAL AEROMETRIC DATA BANK
YEARLY FREQUENCY DISTRIBUTION
STATE (13): GEORGIA

11

SITECODE: 130200092
AGENCY/PROJECT: 002
AGENCY TYPE: COUNTY
CITY POPULATION: 495,973
AQCR POPULATION: 1,719,336
EPA-REGION: 4
SUPPORTING AGENCY: FULTON COUNTY HEALTH DEPT AIR POLLUTION CONTROL SECTION
COMMENTS: CHATTAHOOCHEE WATER TREATMENT PLANT CORNER BOLTON RD & MARIETTA RD

LOCATION: ATLANTA
COUNTY (22601): FULTON CO
SITE ADDR: 2532 BOLTON RD
STATION TYPE (211): SUBURBAN - INDUSTRIAL
AQCR (056): METROPOLITAN ATLANTA
SMSA (0520): ATLANTA, GEORGIA

LATITUDE: 33 D. 49 M. 20 S. N
LONGITUDE: 84 D. 27 M. 10 S. W
UTM ZONE: 16
UTM NORTHING: 3745200
UTM EASTING: 00735750
ELEVATION ABOVE GROUND: 027 FT.
ELEVATION ABOVE MSL: 0820 FT.
DIFF. GMT: WEST 05 HOURS

YEAR	POLLUTANT / POLLUTANT-METHOD CODE / METHOD / INTERVAL AND UNITS	NUM OBS	MIN OBS	10	30	50	PERCENTILES 70	90	95	99	MAX OBS	ARITH AVG	GEOMETRIC MEAN	GEOMETRIC STD DEV
74	PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	55	17.	20.	46.	58.	77.	109.	140.	181.	181.	66.	57.73	1.72
75	PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	24.	29.	35.	60.	70.	105.	124.	124.	124.			

Fig. A-1. SAROAD Yearly Frequency Distribution.

10-02-75 NATIONAL AEROMETRIC DATA BANK 11

QUARTERLY FREQUENCY DISTRIBUTION

STATE (11): GEORGIA

SITECODE: 110200042
AGENCY/PROJECT: GDZ
AGENCY TYPE: COUNTY
CITY POPULATION: 496,973
AQCR POPULATION: 1,719,336
EPA-REGION: 4
SUPPORTING AGENCY: FULTON COUNTY HEALTH DEPT AIR POLLUTION CONTROL SECTION
COMMENTS: CHATTAHOOCHEE WATER TREATMENT PLANT CORNER BOLTON RD & MARIETTA R

LOCATION: ATLANTA
COUNTY (2260): FULTON CO
SITE ADDR: 2532 BOLTON RD
STATION TYPE (21): SUBURBAN - INDUSTRIAL
AQCR (056): METROPOLITAN ATLANTA
SMSA (0520): ATLANTA, GEORGIA

LATITUDE: 33 D. 49 M. 20 S. N
LONGITUDE: 88 D. 27 M. 10 S. W
UTM ZONE: 16
UTM NORTHING: 3745200
UTM EASTING: 00735750
ELEVATION ABOVE GROUND: 027 FT.
ELEVATION ABOVE MSL: 0820 FT.
DIFF. GMT: WEST 05 HOURS

YEAR-QUARTER POLLUTANT / POLLUTANT-METHOD CODE / METHOD / INTERVAL AND UNITS	NUM OBS	MIN OBS	PERCENTILES 10	30	50	70	90	95	99	MAX OBS	ARITH AVG	GEOMETRIC MEAN	STD DEV
74-01 PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	10	18.	18.	60.	71.	95.	109.	173.	173.	173.	83.	72.27	1.89
74-02 PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	30.	35.	43.	57.	69.	98.	181.	181.	181.	65.	58.13	1.59
74-03 PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	17.	20.	26.	47.	56.	106.	109.	109.	109.	51.	93.69	1.81
74-04 PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	32.	38.	54.	59.	86.	125.	140.	140.	140.	71.	65.29	1.55
75-01 PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	24.	25.	35.	60.	70.	105.	124.	124.	124.	59.	52.30	1.69

Fig. A-2. SAROAD Quarterly Frequency Distribution

YEARLY REPORT BY QUARTERS
STATE (13): GEORGIA

SITECODE: 110200042
AGENCY/PROJECT: 602
AGENCY TYPE: COUNTY
CITY POPULATION: 496,973
AQCR POPULATION: 1,718,336
EPA-REGION: 4
SUPPORTING AGENCY: FULTON COUNTY HEALTH DEPT AIR POLLUTION CONTROL SECTION
COMMENTS: CHATTAHOOCHEE WATER TREATMENT PLANT CORNER BOLTON RD & MARIETTA RD

LOCATION: ATLANTA
COUNTY (121): FULTON CO
SITE ADDR: 2537 BOLTON RD
STATION TYPE (21): SUBURBAN - INDUSTRIAL
AQCR (056): METROPOLITAN ATLANTA
SMSA (0520): ATLANTA, GEORGIA

LATITUDE: 33 D. 49 M. 20 S. N
LONGITUDE: 84 D. 27 M. 10 S. W
UTM ZONE: 16
UTM NORTHING: 3745200
UTM EASTING: 0735750
ELEVATION ABOVE GROUND: 027 FT.
ELEVATION ABOVE MSL: 0820 FT.
DIFF. GMT: WEST 05 HOURS

POLLUTANT / POLLUTANT-METHOD CODE / METHOD / INTERVAL AND UNITS	Year	PERCENT OF POSSIBLE OBS	ARITHMETIC AVERAGE	STD DEV	EXTREMES MIN OBS	EXTREMES MAX OBS	QUARTER FIRST NUM OBS	FIRST ARITH AVG	SECOND NUM OBS	SECOND ARITH AVG	THIRD NUM OBS	THIRD ARITH AVG	FOURTH NUM OBS	FOURTH ARITH AVG
74 PARTICULATE (11101) HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)			66.	34.	17.	181.	10	83.	15	65.	15	51.	15	71.

Fig. A-3. SAROAD Yearly Report by Quarters

10-02-75 NATIONAL AEROMETRIC DATA BANK ID-A11

INVENTORY BY SITE

GEORGIA

SITE CODE	AG/ PRJ	LOCATION NAME	POLLUTANT NAME	POL-MTH CODE	INT CODE	UNIT CODE	YEAR	NUM OBS	MAX OBS	ARITH MEAN
110200001	A01	ATLANTA	PARTICULATE	1110191	7	01	1970	26	153.	88.
					7	01	1971	26	139.	83.
					7	01	1972	29	203.	87.
					7	01	1973	28	166.	70.
110200001	G01	ATLANTA	PARTICULATE	1110191	7	01	1973	189	141.	
					7	01	1974	256	131.	58.
110200001	P01	ATLANTA	PARTICULATE	1110191	7	01	1974	7	87.	
110200031	G01	ATLANTA	PARTICULATE	1110191	7	01	1973	16	89.	
					7	01	1974	60	118.	50.
110200032	G01	ATLANTA	PARTICULATE	1110191	7	01	1973	38	77.	
					7	01	1974	55	139.	44.
110200034	F01	ATLANTA	PARTICULATE	1110191	7	01	1973	56	210.	
					7	01	1974	219	198.	84.
110200035	G01	ATLANTA	PARTICULATE	1110191	7	01	1973	16	114.	
					7	01	1974	60	116.	59.
110200036	G02	ATLANTA	PARTICULATE	1110191	7	01	1973	16	80.	
					7	01	1974	56	87.	45.
110200038	G02	ATLANTA	PARTICULATE	1110191	7	01	1973	15	116.	
					7	01	1974	53	103.	61.
110200039	G01	ATLANTA	PARTICULATE	1110191	7	01	1973	45	263.	
					7	01	1974	58	319.	99.
110200040	G02	ATLANTA	PARTICULATE	1110191	7	01	1973	41	132.	
					7	01	1974	60	115.	61.
110200041	G01	ATLANTA	PARTICULATE	1110191	7	01	1973	44	117.	
					7	01	1974	58	89.	53.
110200042	G02	ATLANTA	PARTICULATE	1110191	7	01	1974	55	181.	66.
111600001	F01	DECATUR	PARTICULATE	1110191	7	01	1972	12	83.	
					7	01	1973	19	81.	
					7	01	1974	44	138.	49.

Fig. A-4. SAROAD Inventory by Site

10-02-75 NATIONAL AEROMETRIC DATA BANK 10-C..

INVENTORY BY POLLUTANT

PARTICULATE

POL-MTH CODE	POLLUTANT NAME	SITE CODE	AGY PRJ	LOCATION NAME	INT CODE	UNIT CODE	YEAR	NUM OBS	MAX OBS	ARITH MEAN
1110191	PARTICULATE	110200001	601	ATLANTA	7	01	1970	24	153.	88.
					7	01	1971	24	139.	83.
					7	01	1972	29	203.	87.
					7	01	1973	29	166.	70.
		110200001	601	ATLANTA	7	01	1973	189	141.	
					7	01	1974	256	131.	58.
		110200001	601	ATLANTA	7	01	1974	7	87.	
		110200031	601	ATLANTA	7	01	1973	16	84.	
					7	01	1974	60	118.	50.
		110200032	601	ATLANTA	7	01	1973	38	77.	
					7	01	1974	55	134.	44.
		110200034	601	ATLANTA	7	01	1973	56	210.	
					7	01	1974	219	198.	84.
		110200035	601	ATLANTA	7	01	1973	16	114.	
					7	01	1974	60	116.	59.
		110200036	602	ATLANTA	7	01	1973	16	80.	
					7	01	1974	56	87.	45.
		110200038	602	ATLANTA	7	01	1973	15	116.	
					7	01	1974	53	103.	61.
		110200039	601	ATLANTA	7	01	1973	45	263.	
					7	01	1974	58	319.	99.
		110200040	602	ATLANTA	7	01	1973	41	132.	
					7	01	1974	60	115.	61.
		110200041	601	ATLANTA	7	01	1973	49	117.	
					7	01	1974	58	89.	53.
		110200042	602	ATLANTA	7	01	1974	55	181.	66.
		111600001	601	DECATUR	7	01	1972	12	83.	
					7	01	1973	19	81.	
					7	01	1974	44	138.	49.

Fig. A-5. SAROAD Inventory by Pollutant within State

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RAW DATA LISTING 24-HOUR
111019101 PARTICULATE
REPORTED IN UG/CU METER (25 C)

SITE NAME	SITECODE	AGENCY/PROJECT	YEAR	MONTH	DAY	VALUE
ATLANTA GEORGIA	110200042	002	74	FEB	04	68.
					10	46.
					16	18.
					22	60.
					28	95.
				MAR	06	87.
					12	109.
					18	173.
					24	71.
					30	104.
				APR	05	65.
					11	71.
					17	98.
					23	85.
					29	181.
				MAY	05	39.
					11	57.
					17	67.
					23	48.
					29	37.
				JUN	04	30.
					10	35.
					16	51.
					22	43.
					28	69.
				JUL	04	23.
					10	109.
					16	106.
					22	51.
					28	48.
				AUG	03	20.
					09	48.
					15	61.
					21	46.
					27	90.
				SEP	02	24.
					08	29.
					14	47.
					20	56.
					26	17.
				OCT	02	54.
					08	77.
					20	55.
					26	125.
				NOV	01	91.
					07	97.
					13	58.

Fig. A-6. SAROAD Listing for Data with Averaging Times Greater Than or Equal to 24 Hours or Composite Data

NATIONAL AEROMETRIC DATA BANK STANDARDS REPORT FROM JAN 1974 TO DEC 1974

SITECODE: 110270002
AGENCY/NAMEKEY: GA2
AGENCY TYPE: COUNTY
CITY POPULATION: 496,973
AQCR POPULATION: 1,218,336
EPA-REGION: 4
SUPPORTING AGENCY: FULTON COUNTY HEALTH DEPT AIR POLLUTION CONTROL SECTION
COMMENTS: CHATTAHOOCHEE WATER TREATMENT PLANT CORNER BOLTON RD & MARIETTA RI

LOCATION: ATLANTA
COUNTY(22AD): FULTON CO
SITE ADDR: 2532 BOLTON RD
STATION TYPE (21): SUBURBAN - INDUSTRIAL
AQCR (AREA): METROPOLITAN ATLANTA
SMSA (0520): ATLANTA, GEORGIA

LATITUDE: N33 D. 49 M. 20 S.
LONGITUDE: W 84 D. 27 M. 10 S.
UTM ZONE: 16
UTM NORTHING: 3,745.2 KM.
UTM EASTING: 735.7 KM.
ELEVATION ABOVE GROUND: 27 FT.
ELEVATION ABOVE MSL: 820 FT.
TIME ZONE: WEST 05 HOURS

		JAN 1974	FEB 1974	MAR 1974	APR 1974	MAY 1974	JUN 1974	JUL 1974	AUG 1974	SEP 1974	OCT 1974	NOV 1974	DEC 1974
	1	T	8	8	M	W	S	M	T	S	T	91 F	74 S
	2	M	S	S	T	T	S	T	F	26 M	54 W	S	M
D	3	T	S	S	W	F	M	W	20 S	T	T	S	T
	4	F	48 M	M	T	S	30 T	23 T	S	W	F	M	W
A	5	S	T	T	46 F	39 S	M	F	M	T	S	T	T
	6	S	M	87 M	S	M	T	S	T	F	S	W	F
T	7	M	T	T	S	T	F	S	W	S	M	97 T	43 S
	8	T	F	F	M	W	S	M	T	24 S	77 T	F	S
	9	W	S	S	T	T	S	T	48 F	M	W	S	M
O	10	T	46 S	S	W	F	35 M	109 W	S	T	T	S	T
	11	F	M	M	71 T	57 S	T	T	S	W	F	M	W
F	12	S	T	100 T	F	S	W	F	M	T	S	T	T
	13	S	W	W	S	M	T	S	T	F	S	68 W	140 F
	14	M	T	T	S	T	F	S	W	47 S	M	T	S
M	15	T	F	F	M	W	S	M	61 T	S	T	F	S
	16	W	18 S	S	T	T	51 S	106 T	F	M	W	S	M
O	17	T	S	S	98 W	67 F	M	W	S	T	T	S	T
	18	F	M	173 M	T	S	T	T	S	W	F	M	W
N	19	S	T	T	F	S	W	F	M	T	S	59 T	38 T
	20	S	W	W	S	M	T	S	T	56 F	55 S	W	F
T	21	M	T	T	S	T	F	S	46 W	S	M	T	S
	22	T	60 F	F	M	W	43 S	51 M	T	S	T	F	S
M	23	W	S	S	86 T	48 T	S	T	F	M	W	S	M
	24	T	S	71 S	W	F	M	W	S	T	T	S	T
	25	F	M	M	T	S	T	T	S	W	F	86 M	32 W
	26	S	T	T	F	S	W	F	M	17 T	125 S	T	T
	27	S	W	W	S	M	T	S	90 T	F	S	W	F
	28	M	95 T	T	S	T	49 F	44 S	W	S	M	T	S
	29	T		F	181 M	37 W	S	M	T	S	T	F	S
	30	W		104 S	T	T	S	T	F	M	W	S	M
	31	T		S		F		W	S		T		41 T
NUMBER			5	5	5	5	5	5	5	5	4	5	6
MAXIMUM			95	173	181	67	49	109	90	56	125	97	140
GEO MEAN			60	104	93	48	44	57	48	31	73	76	53

TOTAL SAMPLES = 65
PERCENT OF POSSIBLE OBSERVATIONS = 15.0

STARRED (*) ITEMS EXCEEDED THE PRIMARY STANDARD OF 260 MICROGRAMS PER CUBIC METER
2 PLUSSED (+) ITEMS EXCEEDED THE SECONDARY STANDARD OF 150 MICROGRAMS PER CUBIC METER

GEOMETRIC MEAN = 68
GEOMETRIC STANDARD DEVIATION = 1.92

PRIMARY STANDARD OF 75 MICROGRAMS PER CUBIC METER WAS MET
SECONDARY STANDARD OF 60 MICROGRAMS PER CUBIC METER WAS MET

COLLECTION METHOD: HI-VOL
ANALYSIS METHOD: GRAVIMETRIC
ALL TIMES ARE STANDARD TIME

Fig. A-7. SAROAD Listing Comparing Data to Standards.

APPENDIX B
EMISSIONS DATA FORMATS AVAILABLE FROM NEDS

Examples of several NEDS formats useful in an attainment/maintenance analysis are given in this appendix. There are other available formats that are not included. A short description of each format and the retrieval options follows:

Figure B-1. Point Source Listing. By far most voluminous of all NEDS reports, this listing provides a page for each SCC of each emission point, showing all NEDS information as it appears on the latest NEDS coding sheet. If a plant has three emission points, each point having two SCC codes, there will be six pages of computer printout for the plant. The volume of output may be greatly reduced by various select options built into this program. The report selects all emission points in one of the following categories:

State
State/County
State/County/Plant/Point
SCC (any part I; I + II; I + II + III)
Ownership Code
SIC
Emission Estimate Method
Any combination of the above
AQCR

The point sources can be sorted by the following options:

State	Pollutant Value
County	Year of Record
Plant Number	Control Efficiency
Point Number	Control Equipment
SCC	Sulfur Content
Ownership	Ash Content
SIC	City
Estimation Method	UTM Coordinates
AQCR	Operating Rate
Plant Name	Confidentiality

Figure B-2. Area Source Report. This option, if selected, will produce for the Region, State, or given County, the format of Figure B-2. The data presented should be exactly what the latest NEDS from submitted by the respective states for each County indicated. The retrieval keys are as follows:

State
State/County

Figure B-3. Stationary Source Fuel Summary. This report summarizes area and point source fuel usage for stationary sources. The retrieval keys are as follows:

Nation
State
AQCR
County

Figure B-4. SCC Emissions Report. Total emissions in tons/year of SIP pollutants by county number and SCC category are summarized in this format. Also given is the number of sources available per SCC for each county.

Figure B-5. Annual Fuel Summary Report. This option, if selected, will produce for the Region, State, or given County, the format of Figure B-5. The data presented should be exactly what the latest NEDS form submitted by the respective states for each County indicated. The retrieval keys are as follows:

State
State/County

N E D S A I R E M I S S I O N D A T A S Y S T E M

P O I N T S O U R C E L I S T I N G

STATE:[illegible] DETROIT ATLANTA — CITY:[illegible] ATLANTA
COUNTY:[illegible] FULTON CO — PLANT ID: [illegible] POINT ID: [illegible]

NAME-ADDRESS: ATLANTIC STEEL [illegible] ATLANTA [illegible] SIC:[illegible]: BLAST FURNACES (INCLUDING COKE OVENS), STEEL WORKS & ROLLING MILLS
PERSONAL CONTACT: [illegible] SCC:[illegible]: INDUSTRIAL PROCESS -PRIMARY METALS -STEEL PRODUCTION -ELECT ARC W/LANCE

GENERAL INFORMATION

YEAR OF RECORD: 1971

OWNERSHIP: PRIVATE

IPP PROCESS: [illegible]

SOURCE PROCESS

NORMAL OPERATIONS

DAYS/WEEK: 7

WEEKS/YEAR: 52

% ANNUAL THROUGHPUT

SEPTEMBER: 25 %
MARCH: 25 %
JUNE: 25 %
SEPTEMBER: 25 %

% SPACE HEAT: [illegible] %

COMPLIANCE DATE

NOT SPECIFIED

SCHEDULE

COMPLIANCE DATE: / /

COMPLIANCE STATUS

UPDATE: / /

EMERGENCY CONTROL ACTION PLAN

STATUS:

UNCLASSIFIED EMISSIONS

TSP: [illegible] TONS/YR
PERMITTED: [illegible] TONS/YR

STACK VARIABLES

STACK HEIGHT: [illegible] FT
STACK DIAMETER: [illegible] FT
GAS TEMPERATURE: [illegible] F
GAS FLOW RATE: [illegible] ACFM
PLUME RISE: [illegible] FT
SOME STACK USED [illegible] DIAM

CONTROL EQUIPMENT IDENTIFICATION

PRIMARY PART: FABRIC FILTER W HIGH TEMPERATURE
SECONDARY PART: NO CONTROL EQUIPMENT

PRIMARY SO2: NO CONTROL EQUIPMENT
SECONDARY SO2: NO CONTROL EQUIPMENT

PRIMARY NOX: NO CONTROL EQUIPMENT
SECONDARY NOX: NO CONTROL EQUIPMENT

PRIMARY HC: NO CONTROL EQUIPMENT
SECONDARY HC: NO CONTROL EQUIPMENT

PRIMARY CO: NO CONTROL EQUIPMENT
SECONDARY CO: NO CONTROL EQUIPMENT

FUEL CHARACTERISTICS

FUEL SULFUR CONTENT: [illegible] %

FUEL ASH CONTENT: [illegible] %

FUEL HEAT CONTENT:

HAND CALCULATED EMISSION ESTIMATES

PARTICULATE:	19	TONS/YR
SO2:	[illegible]	TONS/YR
NOX:	[illegible]	TONS/YR
HC:	[illegible]	TONS/YR
CO:	1,530	TONS/YR

EMISSION ESTIMATION METHODS

PART: EMISSION FACTOR(AP-42) OR PENGILLY
SO2: NOT APPLICABLE
NOX: NOT APPLICABLE
HC: NOT APPLICABLE
CO: EMISSION FACTOR(AP-42) OR PENGILLY

CONTROL EFFICIENCIES

PART: 98.[illegible] %
SO2: [illegible] %
NOX: [illegible] %
HC: [illegible] %
CO: [illegible] %

OPERATING RATES

ANNUAL OPERATING RATE: [illegible] TONS PRODUCED
HOURLY MEAN DESIGN RATE:
HOURLY DESIGN CAPACITY:

ALLOWABLE EMISSIONS

PARTICULATE:	134	TONS/YR
SO2:	0	TONS/YR
NOX:	0	TONS/YR
HC:	0	TONS/YR
CO:	0	TONS/YR

COMPUTER CALCULATED EMISSIONS

PART:	19	TONS/YR
SO2:		TONS/YR
NOX:		TONS/YR
HC:		TONS/YR
CO:	1,530	TONS/YR

COMMENTS:

Fig. B-1. NEDS Point Source Listing

SOURCE ID: A STATE- 1[illegible] COUNTY- [illegible] AQCR- [illegible] YEAR- 7[illegible]

EM-EST-PRT(100-TONS)	38	EM-EST-SO2(100-TONS)	40	EM-EST-NOX(100-TONS)	420	EM-EST-HC(100-TONS)	1039
EM-EST-CO(100-TONS)	[illegible]	% SULF-ANTH-COAL		% SULF-BITUM-COAL	1.7	% SULF-DIST-OIL	0.1
% SULF-RESID-OIL	0.2	% ASH-ANTH-COAL		% ASH-BITUM-COAL	7.4	RES-ANTH(10-TONS)	
RES-BITUM(10-TONS)	[illegible]	RES-DIS-OIL(10E4-GAL)	[illegible]	RES-RID-OIL(10E4-GAL)		RES-N-GAS(10E7-CUFT)	1612
RES-WOOD(100-TONS)	24	CI-ANTH(10-TONS)		CI-BITUM(10-TONS)		CI-DIS-OIL(10E4-GAL)	1501
CI-RID-OIL(10E4-GAL)	1407	CI-N-GAS(10E7-CUFT)	[illegible]	CI-WOOD(100-TONS)		IND-ANTH(10-TONS)	
IND-BITUM(10-TONS)	[illegible]	IND-COKE(10-TONS)		IND-DIS-OIL(10E4-GAL)	1537	IND-RD-OIL(10E4-GAL)	0
IND-N-GAS(10E7-CUFT)	[illegible]	IND-WOOD(100-TONS)		IND-RD-GAS(10E7-CUFT)			
RES-OS-INC(10-TONS)	[illegible]	IND-OS-INC(100-TONS)	[illegible]	CI-OS-INC(100-TONS)	135	PART-EMS(T/YR)	[illegible]
RES-OP-DPN(100-TONS)	[illegible]	IND-OPN-DPN(100-TONS)	[illegible]	CI-OPN-DPN(100-TONS)	[illegible]	SO2-EMS(T/YR)	5304.593
GAS-LT-VEH(1000-GAL)	[illegible]	GAS-HVY-VEH(1000-GAL)	[illegible]	GAS-OFF-HWY(1000-GAL)	[illegible]	NOX-EMS(T/YR)	[illegible]
DIE-HV-VEH(1000-GAL)	[illegible]	DIE-OFF-HWY(10E4-GAL)	[illegible]	DIE-RR-LOC(10E4-GAL)	[illegible]	HC-EMS(T/YR)	[illegible]
COUNTY-POP(1000)	[illegible]	DENSITY-COUL	[illegible]	MIL-AIRCRAFT(100-LTO)	40	CO-EMS(T/YR)	[illegible]
CIV-AIRCRAFT(10-LTO)	0	COMM-AIRCRAFT(10-LTO)	[illegible]	VES-BITUM(10-TONS)	0	NO. 6-EMS(T/YR)	0.000
VES-DIE-OIL(10E4-GAL)	0	VES-RID-OIL(10E4-GAL)	0	VES-GAS(1000-GAL)	0	NO. 7-EMS(T/YR)	0.000
EVAP-SOLVENT(T/YR)	[illegible]	EVAP-GAS(10E4-GAL)	[illegible]	VEH-MI-LA-PC(10E4-MI)		NO. 8-EMS(T/YR)	0.000
VEH-MI-RURL(10E4-MI)	[illegible]	VEH-MI-SUBAN(10E4-MI)		VEH-MI-URBAN(10E4-MI)	[illegible]	NO. 9-EMS(T/YR)	0.000
DIRT-RD-TRV(1000-MI)		DIRT-AIR-STRIPS(LTO)		CONST-LAND(1000-ACRE)		NO. 10-EMS(T/YR)	0.000
ROCK-H-ST(1000-TONS)		FOREST-FIRE-AR(ACRES)		FOR-FIRE-GU(TON/ACRE)		NO. 11-EMS(T/YR)	0.000
SLASH-BRN-ARE(ACRES)		SLASH-BN-GU(TON/ACRE)		ORCHARD-HEATERS(10L)	0	NO. 12-EMS(T/YR)	0.000
ORCH-DA-FIRED(DA/YR)	0.0	STRUCTURE-FIRES(#/YR)		CRP-SIZE-SK(100-CUYD)	0		
COAL-REF-BURN(#/YR)	0	COMMENTS					

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Fig. B-2. NEDS Area Source Report

STATIONARY SOURCE FUEL SUMMARY REPORT

NATIONAL EMISSION DATA SYSTEM

ENVIRONMENTAL PROTECTION AGENCY

USER FILE CREATEDATE
FRIDAY DECEMBER 06, 1979

STATE FUEL REPORT: GEORGIA

DATE OF RUN
12/14/79

CURRENT ANNUAL FUEL SUMMARY

	ANTH COAL TONS	BITM COAL TONS	RESID OIL 1000 GALS	DIST OIL 1000 GALS	NAT GAS 10E6 CUFT	PROC GAS 10E6 CUFT	COKE TONS	WOOD TONS
AREA SOURCES								
RESIDENTIAL		57600		99110	99190			
INDUSTRIAL		136320	1260	74970	84910			289400
COMM-INSTL			315000	295820	49230			
TOTAL		193920	316260	369900	233280			289400
POINT SOURCES								
EXT COMB								
ELEC GEN		10116310	25519		57763			
INDUSTRIAL		186062	311592	8079	40334			2250635
COMM-INSTL		3208	620	8102	3052			
TOTAL		10305580	337726	16176	101199			2250635
INPROCESS		75700						
INTERNL COMB								
ELEC GEN								
INDUSTRIAL								
COMM-INSTL								
TOTAL								
GRAND TOTAL		10575200	653986	386076	334929			2540035

	LIGNITE TONS	BAGASSE TONS	SW/COAL TONS	LIG-PETRO 1000 GALS	DIESEL 1000 GALS	GASOLINE 1000 GALS	JET FUEL 1000 GALS
POINT SOURCES							
EXT COMB							
ELEC GEN							
INDUSTRIAL		6670		1302			
COMM-INSTL				7			
INTERNL COMB							
ELEC GEN							
INDUSTRIAL							
COMM-INSTL							
ENG-TEST							
TOTAL		6670		1309			
GRAND TOTAL		6670		1309			

Fig. B-3. NEDS Stationary Source Fuel Summary

***** [illegible] REPORT [illegible]/[illegible]***** UPDATE DATE: MONDAY AUGUST 25, 1975

TABLE 10 *****	SCC ***	[illegible] ****	PART ****	SO2 ***	NOX ***	HC **	CO **
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14.7
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.5	0.7
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.1	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	1.1	[illegible]	0.1	0.1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21.7
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.4
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.3	0.0	0.1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13.6
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.2	0.2
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	97.5	[illegible]	7.9
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.8
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0
[illegible]	[illegible]	[illegible]	[illegible]	0.0	0.0	0.0	0.0

Fig. B-4. NEDS SCC Emissions Report

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NEDS ANNUAL FUEL SUMMARY REPORT

STATE: GEORGIA — USER FILE CREATE DATE: THURSDAY JUNE 19, 1975

COUNTY: FULTON — DATE OF RUN: 06/12/75

	ANTH COAL	BITH COAL	RESID OIL	DIST OIL	NAT GAS	WOOD/BARK	GASOLINE	DIESEL
	TONS	TONS	1000 GALS	1000 GALS	1000 CUFT	TONS	1000 GALS	1000 GALS
AREA SOURCES								
STATIONARY								
RESIDENTIAL		3290		2970	16120	2400		
INDUSTRIAL		21850		13870	13520			
COMM-INSTL			14070	15010	6540			
AREA TOTAL		25140	14070	31850	36180	2400		
POINT SOURCES								
EXT COMB								
ELEC GEN								
INDUSTRIAL		27679	369	50	2570			
COMM-INSTL				6836	833			
INPROCESS		18000	92	1053	16795			
INTERNL COMB								
ELEC GEN								
INDUSTRIAL								
COMM-INSTL								
POINT TOTAL		47679	456	7939	20198			
GRAND TOTAL		72819	14526	39789	56328	2400		

	LIGNITE	COKE	BAGASSE	PROCESS GAS	LIQ-PETRO	JET FUEL	SOLID WASTE	LIQUID WASTE
	TONS	TONS	TONS	1000 CUFT	1000 GALS	1000 GALS	TONS	1000 GALS
POINT SOURCES								
EXT COMB								
ELEC GEN								
INDUSTRIAL					134			
COMM-INSTL								
INPROCESS								
INTERNL COMB								
ELEC GEN								
INDUSTRIAL								
COMM-INSTL								
GRAND TOTAL					134			

Fig. B-5. NEDS Annual Fuel Summary Report

APPENDIX C
COUNTY X CENSUS DATA

This appendix contains population and housing statistics compiled by the Bureau of the Census, U.S. Department of Commerce. County X is assumed to be equivalent to Fulton County, Georgia. The data included are the following:

1. From County Business Patterns, 1973 - Georgia
   Report No. CBP-73-12

   Figure C-1. The State: 1973 and 1972 (Table 1A in the report).

   Figure C-2. Counties: 1973 - Fulton County (Table 2 in the report).

2. From Statistical Abstract of the U.S., 1974

   Figure C-3. Population-States: 1960 to 1973 (Table 11 in the report).

3. From 1970 Census of Housing, Georgia
   Detailed Housing Characteristics Report No. HC(1)-B12

   Figure C-4. Occupancy, Utilization, and Plumbing Characteristics for the State: 1970 (Table 32 in the report).

   Figure C-5. Fuels and Appliances for the State: 1970 (Table 37 in the report).

   Figure C-6. Occupancy, Utilization, and Plumbing Characteristics for Counties: 1970 (Table 60 in the report).

   Figure C-7. Fuels and Appliances for Counties: 1970 (Table 63 in the report).

TABLE 1A The State: 1973 and 1972

(Excludes government employees, railroad employees, self-employed persons, etc. See "General Explanation." [D] denotes figure withheld to avoid disclosure of operations of individual reporting units)

SIC code	Major industry group	1973 Number of employees, mid-March pay period	1973 Taxable payroll for the quarter ($1,000)	1973 Total reporting units	1972 Number of employees, mid-March pay period	1972 Taxable payroll for the quarter ($1,000)	1972 Total reporting units
	TOTAL	1 936 161	2 [illegible]	[illegible]	1 941 149	2 189 [illegible]	80 511
..	AGRICULTURAL SERVICES,FORESTRY,FISHERIES,						
07	AGRICULTURE SERVICES AND HUNTING,	8 579	7 808	963	8 254	6 827	876
08	FORESTRY,	5 795	6 824	822	5 618	5 815	790
09	FISHERIES	513	745	64	394	802	56
..	MINING,	271	239	77	242	210	70
10	METAL MINING,	6 726	14 476	150	6 556	13 820	147
13	OIL AND GAS EXTRACTION,	(D)	(D)	6	196	292	7
14	NONMETALLIC MINERALS, EXCEPT FUELS,	162	425	16	171	447	11
..	CONTRACT CONSTRUCTION	6 349	13 665	121	6 101	12 861	120
15	GENERAL BUILDING CONTRACTORS,	110 831	195 087	9 917	100 658	184 420	8 407
16	HEAVY CONSTRUCTION CONTRACTORS,	35 842	62 819	2 763	31 197	51 328	2 243
17	SPECIAL TRADE CONTRACTORS	21 149	36 633	1 165	19 930	33 210	995
--	ADMINISTRATIVE AND AUXILIARY,	52 902	92 845	5 974	48 866	82 044	5 145
		1 068	2 970	35	885	1 838	24
..	MANUFACTURING	492 160	870 [illegible]	6 [illegible]	480 713	795 157	6 590
19	ORDNANCE AND ACCESSORIES,	(D)	(D)	4	[illegible]	[illegible]	4
20	FOOD AND KINDRED PRODUCTS	47 041	79 127	613	45 133	72 087	626
21	TOBACCO MANUFACTURES,	(D)	(D)	3	[illegible]	[illegible]	4
22	TEXTILE MILL PRODUCTS	118 217	190 800	568	112 382	174 804	507
23	APPAREL AND OTHER TEXTILE PRODUCTS,	71 558	83 988	404	71 262	80 558	451
24	LUMBER AND WOOD PRODUCTS,	24 [illegible]	30 773	1 658	22 370	26 [illegible]	1 623
25	FURNITURE AND FIXTURES,	11 888	17 832	244	12 075	16 677	214
26	PAPER AND ALLIED PRODUCTS	25 [illegible]	64 173	144	25 800	46 [illegible]	136
27	PRINTING AND PUBLISHING	14 741	30 241	652	14 127	28 [illegible]	621
28	CHEMICALS AND ALLIED PRODUCTS	16 310	36 202	270	15 [illegible]	31 [illegible]	263
29	PETROLEUM AND COAL PRODUCTS	[illegible]	1 903	30	[illegible]	1 [illegible]	32
30	RUBBER AND PLASTICS PRODUCTS, N.E.C.,	9 761	17 139	124	8 842	14 844	108
31	LEATHER AND LEATHER PRODUCTS,	4 243	5 168	37	4 543	5 545	28
32	STONE, CLAY, AND GLASS PRODUCTS	17 178	31 990	398	15 [illegible]	28 082	403
33	PRIMARY METAL INDUSTRIES,	10 [illegible]	24 500	72	10 242	19 692	72
34	FABRICATED METAL PRODUCTS	17 [illegible]	33 033	325	16 [illegible]	27 [illegible]	304
35	MACHINERY, EXCEPT ELECTRICAL,	14 578	28 995	428	14 [illegible]	23 [illegible]	404
36	ELECTRICAL EQUIPMENT AND SUPPLIES	11 547	23 277	96	10 [illegible]	21 [illegible]	85
37	TRANSPORTATION EQUIPMENT,	39 447	112 335	202	40 225	111 676	194
38	INSTRUMENTS AND RELATED PRODUCTS,	2 695	[illegible]	40	2 479	[illegible]	33
39	MISCELLANEOUS MANUFACTURING INDUSTRIES,	7 036	11 181	171	6 658	8 416	179
--	ADMINISTRATIVE AND AUXILIARY,	[illegible]	[illegible]	305	13 877	37 914	311
..	TRANSPORTATION AND OTHER PUBLIC UTILITIES	100 544	201 976	2 813	97 998	217 374	2 860
41	LOCAL AND INTERURBAN PASSENGER TRANSIT,	3 745	[illegible]	191	3 [illegible]	[illegible]	187
42	TRUCKING AND WAREHOUSING,	30 782	70 114	1 586	27 811	58 766	1 457
44	WATER TRANSPORTATION,	2 896	2 914	44	1 849	[illegible]	45
45	TRANSPORTATION BY AIR	18 087	69 371	104	16 392	53 368	103
46	PIPE LINE TRANSPORTATION,	242	917	11	[illegible]	1 000	10
47	TRANSPORTATION SERVICES	3 325	7 858	179	2 791	3 598	150
48	COMMUNICATION	27 030	66 123	427	26 362	58 391	425
49	ELECTRIC, GAS AND SANITARY SERVICE,	13 749	37 022	278	14 555	33 [illegible]	265
--	ADMINISTRATIVE AND AUXILIARY,	948	2 687	19	[illegible]	[illegible]	[illegible]
..	WHOLESALE TRADE	117 913	273 942	7 208	111 122	244 040	7 [illegible]
--	ADMINISTRATIVE AND AUXILIARY,	5 197	15 [illegible]	171	5 195	15 169	129
..	RETAIL TRADE,	285 947	355 229	25 [illegible]	273 [illegible]	308 943	24 [illegible]
52	BUILDING MATERIALS & FARM EQUIPMENT	12 [illegible]	19 [illegible]	1 [illegible]	[illegible]	15 282	1 [illegible]
53	GENERAL MERCHANDISE	61 [illegible]	77 [illegible]	1 820	[illegible]	69 [illegible]	1 775
54	FOOD STORES	57 [illegible]	[illegible]	3 114	[illegible]	78 [illegible]	3 [illegible]
55	AUTOMOTIVE DEALERS & SERVICE STATIONS	47 [illegible]	77 [illegible]	6 [illegible]	[illegible]	88 [illegible]	6 [illegible]
56	APPAREL AND ACCESSORY STORES,	17 [illegible]	19 [illegible]	2 041	17 [illegible]	17 [illegible]	2 048
57	FURNITURE AND HOME FURNISHINGS STORES	13 [illegible]	[illegible]	1 [illegible]	[illegible]	17 [illegible]	1 740
58	EATING AND DRINKING PLACES,	[illegible]	[illegible]	3 [illegible]	[illegible]	35 [illegible]	3 [illegible]
59	MISCELLANEOUS RETAIL STORES	29 [illegible]	[illegible]	4 [illegible]	[illegible]	[illegible]	4 [illegible]
--	ADMINISTRATIVE AND AUXILIARY,	[illegible]	17 [illegible]	[illegible]	5 [illegible]	12 [illegible]	[illegible]
..	FINANCE, INSURANCE, AND REAL ESTATE	[illegible]	[illegible]	[illegible]	[illegible]	186 [illegible]	7 [illegible]
60	BANKING	25 [illegible]	48 [illegible]	[illegible]	22 [illegible]	[illegible]	[illegible]
61	CREDIT AGENCIES OTHER THAN BANKS,	11 [illegible]	22 [illegible]	1 [illegible]	11 [illegible]	[illegible]	1 [illegible]
62	SECURITY, COMMODITY BROKERS & SERVICES,	2 [illegible]	[illegible]	[illegible]	2 [illegible]	[illegible]	[illegible]
63	INSURANCE CARRIERS,	[illegible]	[illegible]	[illegible]	22 [illegible]	52 [illegible]	[illegible]
64	INSURANCE AGENTS, BROKERS, & SERVICE,	6 [illegible]	13 [illegible]	1 [illegible]	[illegible]	11 [illegible]	1 [illegible]
65	REAL ESTATE	[illegible]	[illegible]	3 [illegible]	[illegible]	25 [illegible]	2 [illegible]
66	COMBINED REAL ESTATE, INSURANCE, ETC.,	[illegible]	3 [illegible]	[illegible]	[illegible]	2 [illegible]	[illegible]
67	HOLDING AND OTHER INVESTMENT COMPANIES,	1 [illegible]	3 [illegible]	[illegible]	[illegible]	3 [illegible]	[illegible]
--	ADMINISTRATIVE AND AUXILIARY,	[illegible]	[illegible]	5	[illegible]	[illegible]	[illegible]
..	SERVICES,	[illegible]	[illegible]	[illegible]	201 [illegible]	255 [illegible]	20 [illegible]
70	HOTELS AND OTHER LODGING PLACES	23 533	21 [illegible]	1 021	[illegible]	16 [illegible]	1 [illegible]
72	PERSONAL SERVICES	21 [illegible]	22 [illegible]	3 [illegible]	22 [illegible]	32 [illegible]	3 [illegible]
73	MISCELLANEOUS BUSINESS SERVICES	38 112	48 [illegible]	2 125	34 [illegible]	[illegible]	1 [illegible]
75	AUTO REPAIR, SERVICES & GARAGES	10 [illegible]	17 [illegible]	1 [illegible]	10 [illegible]	15 [illegible]	[illegible]
76	MISCELLANEOUS REPAIR SERVICES	5 [illegible]	8 [illegible]	[illegible]	[illegible]	8 [illegible]	[illegible]
78	MOTION PICTURES,	3 [illegible]	3 [illegible]	[illegible]	3 [illegible]	2 [illegible]	[illegible]
79	AMUSEMENT AND RECREATION SERVICES, NEC.	7 503	8 [illegible]	701	[illegible]	[illegible]	[illegible]
80	MEDICAL AND OTHER HEALTH SERVICES	45 [illegible]	70 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
81	LEGAL SERVICES,	5 [illegible]	10 [illegible]	1 [illegible]	[illegible]	7 [illegible]	1 [illegible]
82	EDUCATIONAL SERVICES,	[illegible]	[illegible]	1 [illegible]	18 [illegible]	[illegible]	1 [illegible]
84	MUSEUMS, BOTANICAL, ZOOLOGICAL GARDENS,	107	[illegible]	16	[illegible]	[illegible]	[illegible]
86	NONPROFIT MEMBERSHIP ORGANIZATIONS,	[illegible]	[illegible]	2 [illegible]	22 [illegible]	23 [illegible]	2 [illegible]
89	MISCELLANEOUS SERVICES,	19 [illegible]	33 [illegible]	1 [illegible]	12 [illegible]	25 [illegible]	1 [illegible]
--	ADMINISTRATIVE AND AUXILIARY,	1 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
..	UNCLASSIFIED ESTABLISHMENTS	9 [illegible]	10 [illegible]	[illegible]	11 [illegible]	12 [illegible]	2 [illegible]

Fig. C-1. The State: 1973 and 1972

TABLE 2. Counties: 1973—Continued

(E. Excludes government employees, railroad employees, self-employed persons, etc. See "General Explanation." Size class 1 to 3 includes reporting units having payroll during 1st quarter but no employees during mid-March pay period. "D" denotes figures withheld to avoid disclosure of operations of individual reporting units.)

SIC code	Industry	Number of employees, mid-March pay period	Taxable payroll, Jan.-Mar. 1973 ($1,000)	Total reporting units	Number of reporting units, by employment size class: 1 to 3	4 to 7	8 to 19	20 to 49	50 to 99	100 to 249	250 to 499	500 or more
	FRANKLIN--CON.											
55	AUTOMOTIVE DEALERS & SERVICE STATIONS	146	204	29	19	5	4	1	-	-	-	-
554	GASOLINE SERVICE STATIONS	45	50	14	16	2	1	-	-	-	-	-
57	FURNITURE AND HOME FURNISHINGS STORES	32	33	10	7	2	1	-	-	-	-	-
58	EATING AND DRINKING PLACES	106	70	14	5	3	4	2	-	-	-	-
...	FINANCE, INSURANCE, AND REAL ESTATE	49	86	10	7	1	1	1	-	-	-	-
...	SERVICES	227	288	46	29	10	6	-	1	-	-	-
72	PERSONAL SERVICES	34	22	13	10	3	-	-	-	-	-	-
75	AUTO REPAIR, SERVICES & GARAGES	34	40	10	7	2	1	-	-	-	-	-
...	UNCLASSIFIED ESTABLISHMENTS	(D)	(D)	4	3	-	-	1	-	-	-	-
	FULTON											
	TOTAL	409 512	869 078	16 077	8 072	3 602	3 190	1 809	760	434	138	88
...	AGRICULTURAL SERVICES,FORESTRY,FISHERIES	921	1 266	110	41	39	23	4	3	-	-	-
07	AGRICULTURE SERVICES AND HUNTING	(D)	(D)	109	41	38	23	4	3	-	-	-
072	ANIMAL HUSBANDRY SERVICES	(D)	(D)	47	17	18	8	1	2	-	-	-
073	HORTICULTURAL SERVICES	528	807	61	23	19	15	3	1	-	-	-
...	MINING	298	707	14	3	9	1	3	1	1	-	-
13	OIL AND GAS EXTRACTION	103	285	4	-	2	-	1	1	-	-	-
14	NONMETALLIC MINERALS, EXCEPT FUELS	181	349	5	-	1	1	2	-	1	-	-
142	CRUSHED AND BROKEN STONE	(D)	(D)	3	-	-	-	2	-	1	-	-
1422	CRUSHED AND BROKEN LIMESTONE	(D)	(D)	2	-	-	-	1	-	1	-	-
...	CONTRACT CONSTRUCTION	23 886	52 275	1 317	376	326	294	210	72	34	4	-
15	GENERAL BUILDING CONTRACTORS	8 089	16 551	385	119	94	78	59	21	9	5	-
16	HEAVY CONSTRUCTION CONTRACTORS	2 656	4 824	144	38	33	29	33	7	4	-	-
161	HIGHWAY AND STREET CONSTRUCTION	950	1 572	54	15	14	10	11	3	1	-	-
162	HEAVY CONSTRUCTION, N.E.C.	1 704	3 249	88	21	19	19	22	4	3	-	-
17	SPECIAL TRADE CONTRACTORS	12 612	29 261	775	217	199	182	114	44	19	-	-
171	PLUMBING, HEATING, AIR CONDITIONING	3 551	9 326	191	48	34	56	34	12	5	-	-
172	PAINTING, PAPER HANGING, DECORATING	675	1 543	59	26	18	7	6	-	2	-	-
173	ELECTRICAL WORK	2 051	5 932	110	14	31	32	16	8	4	-	-
174	MASONRY, STONEWORK, AND PLASTERING	1 444	2 409	103	33	30	21	11	6	2	-	-
1741	MASONRY AND OTHER STONEWORK	652	817	67	21	26	12	4	4	-	-	-
1742	PLASTERING AND LATHING	421	846	13	3	1	3	3	2	1	-	-
1743	TERRAZZO, TILE, MARBLE, MOSAIC WORK	371	747	23	9	3	6	4	-	1	-	-
175	CARPENTERING AND FLOORING	564	1 082	65	24	20	11	9	1	-	-	-
1751	CARPENTERING	299	455	38	14	14	6	3	1	-	-	-
1752	FLOOR LAYING & FLOORWORK, N.E.C.	265	627	27	10	6	5	6	-	-	-	-
176	ROOFING AND SHEET METAL WORK	875	1 755	45	9	12	8	11	5	-	-	-
177	CONCRETE WORK	601	639	39	12	13	6	5	2	1	-	-
179	MISC. SPECIAL TRADE CONTRACTORS	2 576	6 130	133	36	34	29	19	10	5	-	-
1791	STRUCTURAL STEEL ERECTION	409	1 453	17	4	4	4	1	4	-	-	-
1793	GLASS AND GLAZING WORK	190	445	11	2	2	4	3	-	-	-	-
1794	EXCAVATING AND FOUNDATION WORK	(D)	(D)	7	4	2	-	-	-	1	-	-
1796	INSTALLING BLDG. EQUIP., N.E.C.	170	350	5	-	-	3	-	-	1	-	-
1799	SPECIAL TRADE CONTRACTORS, N.E.C.	1 549	3 447	84	26	21	10	12	6	3	-	-
--	ADMINISTRATIVE AND AUXILIARY	529	1 599	13	2	-	5	4	-	2	-	-
...	MANUFACTURING	71 014	166 018	1 022	180	160	230	207	105	87	29	25
20	FOOD AND KINDRED PRODUCTS	7 486	15 506	84	13	15	10	15	11	14	3	3
201	MEAT PRODUCTS	840	1 333	10	2	1	2	1	2	1	1	-
2011	MEAT PACKING PLANTS	(D)	(D)	3	1	-	1	-	1	-	-	-
2013	SAUSAGES AND OTHER PREPARED MEATS	140	233	5	1	1	1	1	1	-	-	-
2015	POULTRY DRESSING PLANTS	(D)	(D)	2	-	-	-	-	-	1	1	-
202	DAIRY PRODUCTS	795	1 845	8	1	-	-	2	2	3	-	-
2026	FLUID MILK	659	1 902	4	-	-	-	-	1	3	-	-
203	CANNED, CURED, AND FROZEN FOODS	402	713	7	-	2	-	2	4	1	-	-
2037	FROZEN FRUITS AND VEGETABLES	328	613	3	-	-	-	-	2	1	-	-
204	GRAIN MILL PRODUCTS	(D)	(D)	4	1	1	-	-	-	2	-	-
2042	PREPARED FEED FOR ANIMALS AND FOWLS	(D)	(D)	3	-	1	-	-	-	2	-	-
205	BAKERY PRODUCTS	2 098	4 497	11	2	-	1	3	1	2	-	2
2051	BREAD, CAKE, AND RELATED PRODUCTS	(D)	(D)	9	2	-	1	3	-	2	-	1
2052	COOKIES AND CRACKERS	(D)	(D)	2	-	-	-	-	1	-	-	1
207	CONFECTIONERY AND RELATED PRODUCTS	(D)	(D)	8	1	2	2	2	1	-	-	-
2071	CONFECTIONERY PRODUCTS	(D)	(D)	8	1	2	2	2	1	-	-	-
208	BEVERAGES	1 923	4 431	15	2	4	2	1	2	2	1	1
2082	MALT LIQUORS	(D)	(D)	1	-	-	-	-	-	1	-	-
2086	BOTTLED AND CANNED SOFT DRINKS	(D)	(D)	5	-	-	1	-	2	-	1	1
2087	FLAVORING EXTRACTS AND SIRUPS, NEC.	138	407	6	1	3	1	-	-	1	-	-
209	MISC. FOODS AND KINDRED PRODUCTS	1 082	1 826	18	2	4	3	4	1	3	1	-
2096	SHORTENING AND COOKING OILS	(D)	(D)	1	-	-	-	-	-	1	-	-
2099	FOOD PREPARATIONS, N.E.C.	853	1 443	11	2	2	1	2	1	2	1	-

Fig. C-2. Counties: 1973 - Fulton County

TABLE 2. Counties: 1973—Continued

Excludes government employees, railroad employees, self-employed persons, etc. See General Explanation. Size class 1 to 3 includes reporting units having payroll during 1st quarter but no employees during mid March pay period. "D" denotes figure withheld to avoid disclosure of operations of individual reporting units.

SIC code	Industry	Number of employees, mid March pay period	Taxable payroll, Jan. Mar. ($1,000)	Total reporting units	Number of reporting units, by employment size class: 1 to 3	4 to 7	8 to 19	20 to 49	50 to 99	100 to 249	250 to 499	500 or more
	FULTON--CON.											
22	TEXTILE MILL PRODUCTS	2 394	2 934	25	5	6	2	5	3	3	2	1
221	WEAVING MILLS, COTTON	1 492	1 821	7	-	2	-	-	2	1	1	1
225	KNITTING MILLS	(D)	(D)	3	1	-	1	-	-	1	-	-
2256	KNIT FABRIC MILLS	(D)	(D)	3	1	-	1	-	-	1	-	-
227	FLOOR COVERING MILLS	119	290	7	2	2	1	2	-	1	-	-
228	YARN AND THREAD MILLS	(D)	(D)	1	-	-	-	-	-	-	-	-
2281	YARN MILLS, EXCEPT WOOL	(D)	(D)	1	-	-	-	-	-	-	1	-
229	MISCELLANEOUS TEXTILE GOODS	(D)	(D)	2	-	-	-	1	-	-	1	-
2291	FELT GOODS, N.E.C.	(D)	(D)	1	-	-	-	-	-	1	-	-
23	APPAREL AND OTHER TEXTILE PRODUCTS	6 749	10 805	62	2	7	10	11	13	14	3	2
232	MEN'S AND BOYS' FURNISHINGS	2 715	4 770	11	-	1	-	2	3	2	2	1
2321	MEN'S & BOYS' SHIRTS AND NIGHTWEAR	(D)	(D)	4	-	-	-	1	1	-	1	1
2327	MEN'S & BOYS' SEPARATE TROUSERS	(D)	(D)	2	-	-	-	-	1	1	1	-
2328	MEN'S & BOYS' WORK CLOTHING	(D)	(D)	2	-	-	-	-	-	1	1	-
233	WOMEN'S AND MISSES' OUTERWEAR	1 199	1 847	15	-	-	-	1	1	1	-	-
2339	WOMEN'S AND MISSES' DRESSES	(D)	(D)	8	-	1	-	3	5	6	-	-
2339	WOMEN'S AND MISSES' OUTERWEAR, NEC.	592	975	7	-	1	-	-	2	3	-	-
234	WOMEN'S AND CHILDREN'S UNDERGARMENTS	(D)	(D)	3	-	-	-	2	2	3	-	-
2342	CORSETS AND ALLIED GARMENTS	(D)	(D)	2	-	1	-	-	1	-	-	1
238	MISCELLANEOUS APPAREL AND ACCESSORIES	347	623	4	-	1	-	-	-	-	-	1
2387	APPAREL BELTS	(D)	(D)	3	-	-	2	-	1	-	1	-
239	MISC. FABRICATED TEXTILE PRODUCTS	1 149	1 841	22	1	3	6	4	2	-	1	-
2391	CURTAINS AND DRAPERIES	310	369	7	1	-	2	2	-	2	-	-
2392	HOUSEFURNISHINGS, N.E.C.	409	586	4	-	-	2	2	-	1	-	-
2394	TENTS, PRODUCTS	(D)	(D)	2	-	1	-	-	1	1	-	-
2399	FABRICATED TEXTILE PRODUCTS, N.E.C.	223	346	5	-	1	1	1	1	1	-	-
24	LUMBER AND WOOD PRODUCTS	1 769	2 219	44	6	5	12	11	7	2	1	-
242	SAWMILLS AND PLANING MILLS	280	376	12	3	-	6	1	-	-	-	-
2421	SAWMILLS AND PLANING MILLS, GENERAL	(D)	(D)	9	2	-	6	1	-	-	-	-
243	MILLWORK, PLYWOOD & RELATED PRODUCTS	800	1 116	10	1	-	-	4	2	1	1	-
2431	MILLWORK	303	405	6	1	-	-	2	2	1	-	-
2432	VENEER AND PLYWOOD	(D)	(D)	1	-	-	-	1	-	-	1	-
2439	PREFABRICATED WOOD STRUCTURES	(D)	(D)	3	-	-	-	1	-	1	-	-
249	MISCELLANEOUS WOOD PRODUCTS	574	774	13	1	2	4	2	3	1	-	-
2491	WOOD PRESERVING	203	367	5	-	-	2	1	2	-	-	-
2499	WOOD PRODUCTS, N.E.C.	371	387	8	1	2	2	1	1	1	-	-
25	FURNITURE AND FIXTURES	2 715	4 247	49	9	10	10	12	1	4	2	1
251	HOUSEHOLD FURNITURE	2 017	3 716	21	5	4	3	3	-	3	2	1
2511	WOOD HOUSEHOLD FURNITURE	(D)	(D)	8	2	1	1	-	-	1	1	-
2514	METAL HOUSEHOLD FURNITURE	(D)	(D)	3	1	-	1	-	-	1	1	-
2515	MATTRESSES AND BEDSPRINGS	1 140	2 [illegible]	10	2	1	1	3	-	2	-	1
254	PARTITIONS AND FIXTURES	357	846	11	2	1	3	4	-	1	-	1
2541	WOOD PARTITIONS AND FIXTURES	(D)	(D)	10	2	1	3	3	-	1	-	-
259	MISCELLANEOUS FURNITURE AND FIXTURES	298	454	5	-	2	-	2	1	-	-	-
2599	FURNITURE AND FIXTURES, N.E.C.	(D)	(D)	3	-	-	-	2	1	-	-	-
26	PAPER AND ALLIED PRODUCTS	5 159	11 [illegible]	36	1	1	3	10	7	9	3	2
261	PAPERBOARD MILLS	(D)	(D)	2	-	-	-	1	-	-	-	-
264	MISC. CONVERTED PAPER PRODUCTS	(D)	(D)	16	-	-	2	6	4	2	2	1
2642	PAPER COATING AND GLAZING	879	1 [illegible]	4	-	-	-	-	2	-	2	-
2643	ENVELOPES	340	678	4	-	-	1	1	1	1	-	-
2645	BAGS, EXCEPT TEXTILE BAGS	(D)	(D)	4	-	-	1	2	1	1	-	-
2648	DIE CUT PAPER AND BOARD	(D)	(D)	2	-	-	-	1	1	-	-	-
2649	SANITARY PAPER PRODUCTS, N.E.C.	(D)	(D)	2	-	-	-	1	1	-	-	-
265	PAPERBOARD CONTAINERS AND BOXES	2 801	6 [illegible]	17	1	1	1	3	3	6	1	1
2651	FOLDING PAPERBOARD BOXES	(D)	(D)	3	-	1	-	1	-	1	-	-
2653	CORRUGATED AND SOLID FIBER BOXES	1 276	2 [illegible]	10	-	-	-	1	2	5	1	1
2656	SANITARY FOOD CONTAINERS	(D)	(D)	3	-	-	-	1	1	1	-	-
27	PRINTING AND PUBLISHING	7 137	16 [illegible]	201	56	67	46	32	19	6	4	1
271	NEWSPAPERS	(D)	(D)	14	3	4	-	3	-	-	4	1
272	PERIODICALS	355	647	23	12	4	3	1	-	1	-	-
273	BOOKS	225	417	7	2	2	-	-	1	1	-	-
2731	BOOK PUBLISHING	(D)	(D)	6	2	2	-	-	1	-	-	-
274	MISCELLANEOUS PUBLISHING	283	276	7	2	-	2	-	2	-	-	-
279	COMMERCIAL PRINTING	3 197	6 [illegible]	119	26	24	27	22	9	3	3	-
2791	COMM. PRINTING, EXCEPT LITHOGRAPHIC	1 445	3 [illegible]	63	15	16	15	10	5	1	1	-
2792	COMMERCIAL PRINTING, LITHOGRAPHIC	1 024	4 [illegible]	44	9	7	10	11	3	2	2	-
2793	ENGRAVING AND PLATE PRINTING	208	241	5	1	1	1	1	1	-	-	-
278	BLANKBOOKS AND BOOKBINDING	211	420	8	1	2	3	1	1	-	-	-
2782	BLANKBOOKS AND LOOSE LEAF BINDERS	101	270	4	-	1	1	1	1	-	-	-
279	PRINTING TRADE SERVICES	263	704	18	3	2	7	4	1	-	-	-
2791	TYPESETTING	152	367	10	3	2	3	1	1	-	-	-
2793	PHOTOENGRAVING	(D)	(D)	5	-	-	3	2	-	-	-	-

Fig. C-2. Counties: 1973 - Fulton County (Continued)

TABLE 2. Counties: 1973—Continued

(Excludes government employees, railroad employees, self-employed persons, etc. [illegible] Explanation. [illegible] (D) denotes figures withheld to avoid disclosure of operations of individual reporting units.)

SIC code	Industry	Number of employees, mid-March pay period	Taxable payroll, Jan.-Mar. ($1,000)	Total reporting units	Number of reporting units, by employment size class: 1 to 3	4 to 7	8 to 19	20 to 49	50 to 99	100 to 249	250 to 499	500 or more
	FULTON--CON.											
28	CHEMICALS AND ALLIED PRODUCTS	3,255	7,721	71	13	8	16	18	7	6	2	1
281	INDUSTRIAL CHEMICALS	306	686	11	-	3	3	3	2	-	-	-
2819	INDUSTRIAL INORGANIC CHEMICALS, NEC	193	448	5	-	-	2	2	1	-	-	-
283	DRUGS	183	407	5	1	1	-	2	-	1	-	-
2834	PHARMACEUTICAL PREPARATIONS	(D)	(D)	4	-	1	-	2	-	1	-	-
284	SOAP, CLEANERS, AND TOILET GOODS	1,368	3,187	24	6	2	4	4	4	2	2	-
2841	SOAP AND OTHER DETERGENTS	(D)	(D)	7	-	-	3	3	1	-	-	-
2842	POLISHES AND SANITATION GOODS	1,081	2,376	15	6	1	1	-	3	2	2	-
285	PAINTS AND ALLIED PRODUCTS	879	1,944	8	-	1	2	1	1	2	-	1
287	AGRICULTURAL CHEMICALS	(D)	(D)	4	1	-	1	1	-	1	-	-
2871	FERTILIZERS	(D)	(D)	3	1	-	1	-	-	1	-	-
289	MISCELLANEOUS CHEMICAL PRODUCTS	391	1,092	15	4	-	5	6	-	-	-	-
2893	PRINTING INK	192	520	7	-	-	6	1	-	-	-	-
30	RUBBER AND PLASTICS PRODUCTS, N.E.C.	1,213	2,576	30	4	5	6	7	6	2	-	-
306	FABRICATED RUBBER PRODUCTS, N.E.C.	187	295	5	1	-	1	2	1	-	-	-
307	MISCELLANEOUS PLASTICS PRODUCTS	1,043	1,746	24	3	5	5	5	5	2	-	-
32	STONE, CLAY, AND GLASS PRODUCTS	4,274	9,[illegible]	44	1	7	10	10	7	4	-	3
322	GLASS AND GLASSWARE, PRESSED OR BLOWN	(D)	(D)	1	-	-	-	-	-	-	-	1
3221	GLASS CONTAINERS	(D)	(D)	1	-	-	-	-	-	-	-	1
323	PRODUCTS OF PURCHASED GLASS	(D)	(D)	3	-	2	-	-	-	1	-	-
324	CEMENT, HYDRAULIC	(D)	(D)	1	-	-	-	-	-	1	-	-
325	STRUCTURAL CLAY PRODUCTS	(D)	(D)	2	-	-	-	-	-	2	-	-
3251	BRICK AND STRUCTURAL CLAY TILE	(D)	(D)	2	-	-	-	-	-	2	-	-
327	CONCRETE, GYPSUM, & PLASTER PRODUCTS	1,[illegible]	2,[illegible]	25	1	1	6	7	5	3	-	-
3271	CONCRETE BLOCK AND BRICK	270	588	8	-	-	4	4	1	-	-	-
3272	CONCRETE PRODUCTS, N.E.C.	492	892	11	-	1	4	1	4	1	-	-
3273	READY-MIXED CONCRETE	345	694	6	1	-	2	1	-	2	-	-
329	MISC. NONMETALLIC MINERAL PRODUCTS	(D)	(D)	6	-	1	-	3	-	-	-	2
3296	MINERAL WOOL	(D)	(D)	3	-	-	-	1	-	-	-	2
33	PRIMARY METAL INDUSTRIES	2,048	5,[illegible]	15	1	3	3	4	1	2	-	1
331	BLAST FURNACE & BASIC STEEL PRODUCTS	(D)	(D)	1	-	-	1	-	-	-	-	1
3312	BLAST FURNACE AND STEEL MILLS	(D)	(D)	1	-	-	-	-	-	-	-	1
332	IRON AND STEEL FOUNDRIES	118	241	4	-	1	-	2	1	-	-	-
334	SECONDARY NONFERROUS METALS	(D)	(D)	2	-	-	-	1	-	1	-	-
339	MISCELLANEOUS PRIMARY METAL PRODUCTS	(D)	(D)	2	-	1	-	-	-	1	-	-
3399	IRON AND STEEL FORGINGS	(D)	(D)	1	-	-	-	-	-	1	-	-
34	FABRICATED METAL PRODUCTS	2,857	6,[illegible]	85	15	9	25	25	6	4	2	-
341	METAL CANS	(D)	(D)	1	-	1	-	1	-	-	-	-
343	PLUMBING AND HEATING, EXCEPT ELECTRIC	(D)	(D)	3	-	1	-	-	1	1	-	-
3433	HEATING EQUIPMENT, EXCEPT ELECTRIC	(D)	(D)	2	-	1	-	-	1	1	-	-
344	FABRICATED STRUCTURAL METAL PRODUCTS	1,344	3,[illegible]	44	7	5	14	14	4	1	1	-
3441	FABRICATED STRUCTURAL STEEL	276	[illegible]	7	1	-	1	4	-	1	-	-
3442	METAL DOORS, SASH, AND TRIM	(D)	(D)	5	1	1	-	1	-	-	1	-
3444	SHEET METAL WORK	442	1,[illegible]	21	1	3	10	4	2	-	-	-
347	METAL SERVICES, N.E.C.	395	[illegible]	12	1	-	5	4	1	-	-	-
3471	PLATING AND POLISHING	202	350	6	1	-	4	1	1	-	-	-
3479	METAL COATING AND ALLIED SERVICES	193	316	6	1	-	1	1	-	1	-	-
348	MISC. FABRICATED WIRE PRODUCTS	115	208	4	1	-	-	1	-	1	-	-
349	MISC. FABRICATED METAL PRODUCTS	379	690	6	-	-	1	2	-	-	1	-
3494	VALVES AND PIPE FITTINGS	(D)	(D)	2	-	-	-	1	-	-	1	-
35	MACHINERY, EXCEPT ELECTRICAL	3,074	8,[illegible]	66	13	10	16	7	7	10	-	1
352	FARM MACHINERY	(D)	(D)	1	-	-	-	-	-	1	-	-
353	CONSTRUCTION AND RELATED MACHINERY	258	7[illegible]	8	-	2	4	2	2	-	-	-
3535	CONVEYOR AND CONVEYING EQUIPMENT	188	5[illegible]	3	-	-	-	1	2	-	-	-
354	METAL-WORKING MACHINERY	170	3[illegible]	4	3	1	-	-	1	-	-	-
3544	SPECIAL DIES, TOOLS, JIGS & FIXTURES	(D)	(D)	7	2	-	-	-	1	-	-	-
355	SPECIAL INDUSTRY MACHINERY	747	1,[illegible]	12	-	2	3	2	2	3	-	-
3553	WOOD PRODUCTS MACHINERY	346	793	3	-	-	-	-	1	2	-	-
3552	TEXTILE MACHINERY	(D)	(D)	4	-	1	1	-	1	1	-	-
356	GENERAL INDUSTRIAL MACHINERY	371	7[illegible]	8	4	-	4	1	1	2	-	-
3569	GENERAL INDUSTRIAL MACHINERY, NEC	(D)	(D)	5	-	-	2	1	-	2	-	-
357	OFFICE AND COMPUTING MACHINES	419	8[illegible]	5	-	1	-	1	1	2	-	-
3576	SCALES AND BALANCES, EXC. ELEC.	(D)	(D)	3	-	-	-	1	-	2	-	-
358	SERVICE INDUSTRY MACHINES	887	1,[illegible]	6	1	-	-	-	-	4	-	1
3585	REFRIGERATION MACHINERY	887	1,[illegible]	4	1	-	-	-	-	2	-	1
359	MISC. MACHINERY, EXCEPT ELECTRICAL	133	31[illegible]	17	7	3	6	1	-	-	-	-
36	ELECTRICAL EQUIPMENT AND SUPPLIES	1,122	2,539	28	5	5	6	8	-	3	1	-
361	ELECTRIC TEST & DISTRIBUTING EQUIP.	270	443	6	2	-	1	2	-	1	-	-
3613	SWITCHGEAR & SWITCHBOARD APPARATUS	(D)	(D)	3	-	-	1	1	-	1	-	-
369	MISC. ELECTRICAL EQUIP. & SUPPLIES	685	1,769	5	-	-	1	1	-	2	1	-
3691	STORAGE BATTERIES	(D)	(D)	4	-	-	-	1	-	2	1	-

Fig. C-2. Counties: 1973 - Fulton County (Continued)

TABLE 2. Counties: 1973—Continued

SIC code	Industry	Number of employees mid-March pay period	Taxable payroll for the quarter ($1,000)	Total reporting units	Number of reporting units, by employment size class: 1 to 3	4 to 7	8 to 19	20 to 49	50 to 99	100 to 249	250 to 499	500 or more
	FULTON--CON.											
37	TRANSPORTATION EQUIPMENT	9 160	76 548	52	9	9	8	5	3	2	2	3
371	MOTOR VEHICLES AND EQUIPMENT	9 447	53 847	23	2	2	7	6	-	1	2	3
3711	MOTOR VEHICLES	(D)	(D)	5	1	-	2	-	-	-	-	2
3712	PASSENGER CAR BODIES	(D)	(D)	1	-	-	-	-	-	-	-	1
3713	TRUCK AND BUS BODIES	(D)	173	5	-	2	2	2	-	-	-	-
3714	MOTOR VEHICLE PARTS AND ACCESSORIES	909	2 197	11	2	1	3	4	-	1	1	-
3715	TRUCK TRAILERS	(D)	(D)	1	-	-	-	-	-	1	-	-
379	MISC. TRANSPORTATION EQUIPMENT	(D)	(D)	2	-	-	-	-	1	1	-	-
3791	TRAILER COACHES	(D)	(D)	1	-	-	-	-	-	-	1	-
38	INSTRUMENTS AND RELATED PRODUCTS	198	700	13	5	1	4	3	-	-	-	-
39	MISCELLANEOUS MANUFACTURING INDUSTRIES	2 012	3 553	50	12	6	16	11	3	-	1	1
394	TOYS AND SPORTING GOODS	402	537	6	2	-	1	1	1	-	1	-
3942	DOLLS	(D)	(D)	2	1	-	-	-	1	-	1	-
3949	SPORTING AND ATHLETIC GOODS, N.E.C.	(D)	(D)	3	1	-	-	1	1	-	-	-
395	PENS, PENCILS, OFFICE & ART SUPPLIES	1 103	1 877	9	1	-	2	4	1	-	-	1
3951	PENS AND MECHANICAL PENCILS	(D)	(D)	1	-	-	-	-	-	-	-	1
3953	MARKING DEVICES	(D)	(D)	1	-	-	2	-	1	-	-	-
399	MISCELLANEOUS MANUFACTURES	623	772	29	9	6	10	6	1	-	-	-
3991	BROOMS AND BRUSHES	(D)	(D)	1	-	-	-	1	-	-	-	-
3993	SIGNS AND ADVERTISING DISPLAYS	186	409	17	3	4	8	2	-	-	-	-
--	ADMINISTRATIVE AND AUXILIARY	493	22 380	78	13	16	24	9	9	-	2	5
...	TRANSPORTATION AND OTHER PUBLIC UTILITIES	67 250	191 724	665	128	70	100	74	34	32	12	15
41	LOCAL AND INTERURBAN PASSENGER TRANSIT	2 471	5 475	61	19	10	8	6	1	4	-	1
411	LOCAL AND SUBURBAN TRANSPORTATION	(D)	(D)	6	2	1	1	-	-	-	-	1
4111	LOCAL AND SUBURBAN TRANSIT	(D)	(D)	1	-	-	-	-	1	-	-	1
412	TAXICABS	373	378	12	14	4	3	-	-	1	-	-
413	INTERCITY HIGHWAY TRANSPORTATION	(D)	(D)	5	1	1	-	-	2	1	-	-
4131	INTERCITY BUS LINES	(D)	(D)	5	1	1	-	-	2	1	-	-
417	BUS TERMINAL AND SERVICE FACILITIES	(D)	(D)	2	-	-	-	-	1	1	-	-
4173	BUS TERMINAL FACILITIES	(D)	(D)	1	-	-	-	-	1	-	-	-
42	TRUCKING AND WAREHOUSING	15 570	41 336	277	56	36	56	50	21	25	6	6
421	TRUCKING, LOCAL AND LONG DISTANCE	10 414	34 894	213	54	23	43	40	16	25	6	6
4211	TRUCKING WITHOUT STORAGE	13 414	38 724	180	47	17	32	34	13	24	6	3
4214	LOCAL TRUCKING AND STORAGE	933	660	26	3	3	10	4	2	1	-	-
422	PUBLIC WAREHOUSING	804	1 646	63	3	13	13	10	5	-	-	-
4222	REFRIGERATED WAREHOUSING, N.E.C.	(D)	(D)	3	-	1	-	-	2	-	-	-
4225	GENERAL WAREHOUSING AND STORAGE	674	1 221	28	1	7	9	6	3	-	-	-
45	TRANSPORTATION BY AIR	16 843	66 945	53	9	8	5	3	4	-	3	3
451	AIR TRANSPORTATION	(D)	(D)	29	8	7	4	2	4	-	3	3
46	PIPE LINE TRANSPORTATION	(D)	(D)	3	1	-	1	-	-	1	-	-
47	TRANSPORTATION SERVICES	594	1 268	68	34	22	15	5	2	-	-	-
472	FREIGHT FORWARDING	513	903	20	6	1	6	1	4	-	-	-
4729	ARRANGEMENT OF TRANSPORTATION	276	410	42	25	6	6	2	-	-	-	-
48	COMMUNICATION	7 691	25 225	35	6	4	12	6	4	-	3	2
481	TELEPHONE COMMUNICATION	(D)	(D)	3	-	-	1	-	-	-	-	2
482	TELEGRAPH COMMUNICATION	(D)	(D)	2	1	-	-	-	-	-	1	-
483	RADIO AND TELEVISION BROADCASTING	(D)	(D)	23	4	3	6	6	1	-	2	-
489	COMMUNICATION SERVICES, N.E.C.	146	365	7	1	1	3	1	2	-	-	-
49	ELECTRIC, GAS AND SANITARY SERVICES	(D)	(D)	9	2	-	3	2	1	1	-	1
492	GAS COMPANIES AND SYSTEMS	(D)	(D)	3	-	-	1	1	-	1	-	1
493	COMBINATION COMPANIES AND SYSTEMS	(D)	(D)	1	-	-	-	-	-	-	-	1
4931	ELECTRIC & OTHER SERVICES COMBINED	(D)	(D)	1	-	-	-	-	-	-	-	1
495	SANITARY SERVICES	104	428	5	1	-	2	1	1	-	-	-
--	ADMINISTRATIVE AND AUXILIARY	702	2 099	8	2	-	-	2	1	3	-	-
...	WHOLESALE TRADE	58 664	148 070	2 383	851	509	576	372	161	70	24	5
501	MOTOR VEHICLES & AUTOMOTIVE EQUIPMENT	5 022	13 949	217	90	56	52	33	16	8	1	1
5012	AUTOMOBILES & OTHER MOTOR VEHICLES	1 255	3 762	28	5	4	2	4	8	4	1	1
5013	AUTOMOTIVE EQUIPMENT	3 843	8 394	166	78	48	44	23	8	4	1	1
5014	TIRES AND TUBES	724	1 813	27	6	4	6	6	-	2	-	1
502	DRUGS, CHEMICALS, AND ALLIED PRODUCTS	6 442	12 439	141	37	24	32	25	16	5	1	1
5022	DRUGS, PROPRIETARIES, AND SUNDRIES	2 195	5 544	36	9	4	8	4	6	4	-	1
5026	PAINTS AND VARNISHES	211	631	13	1	4	4	2	1	-	-	1
5029	CHEMICALS AND ALLIED PRODUCTS, NEC	2 047	6 313	92	27	16	20	18	9	1	1	-
503	DRY GOODS AND APPAREL	2 [illegible]2	6 155	130	45	26	31	17	1	3	1	-
5031	PIECE GOODS	486	1 366	29	7	6	8	6	2	-	-	-
5034	NOTIONS AND OTHER DRY GOODS	508	1 096	15	2	3	4	3	2	1	-	-
5036	MENS CLOTHING AND FURNISHINGS	233	592	24	8	7	5	2	1	-	-	-
5037	WOMENS AND CHILDRENS CLOTHING	1 065	2 410	39	22	9	4	4	1	2	1	-
5039	FOOTWEAR	117	350	10	1	2	7	-	-	-	-	-
504	GROCERIES AND RELATED PRODUCTS	6 096	9 340	179	67	31	50	32	13	6	1	1
5041	GROCERIES, GENERAL LINE	714	1 580	25	5	7	6	4	4	-	1	-
5042	FROZEN FOODS	273	594	15	4	3	5	2	-	1	-	-
5043	DAIRY PRODUCTS	498	1 282	10	3	1	3	2	-	-	-	1
5045	CONFECTIONERY	109	198	14	6	3	3	2	-	-	-	-
5047	MEATS AND MEAT PRODUCTS	596	1 410	25	3	5	6	7	4	-	-	-
5048	FRESH FRUITS AND VEGETABLES	145	298	8	4	1	2	-	2	-	-	-
5049	GROCERIES & RELATED PRODUCTS, NEC	1 628	3 924	74	19	9	23	15	5	3	-	-

Fig. C-2. Counties: 1973 - Fulton County (Continued)

TABLE 2 Counties: 1973—Continued

SIC code	Industry	Number of employees, mid-March pay period	Taxable payroll, Jan.-Mar. ($1,000)	Total reporting units	Number of reporting units, by employment size class: 1 to 3	4 to 7	8 to 19	20 to 49	50 to 99	100 to 249	250 to 499	500 or more
	FULTON—FOR.											
515	FARM PRODUCT RAW MATERIALS.	413	794	11	5	1	2	-	-	-	1	-
5159	FARM PRODUCT RAW MATERIALS, N.E.C.	213	213	2	1	-	-	-	-	-	1	-
516	ELECTRICAL GOODS.	5 570	14 932	193	54	32	61	22	11	6	4	-
5163	ELECTRICAL APPARATUS AND EQUIPMENT.	2 816	8 774	119	35	19	34	11	5	3	1	1
5164	ELECTRICAL APPLIANCES, TV & RADIOS.	1 877	4 148	56	8	6	10	-	4	-	3	-
5165	ELECTRONIC PARTS AND EQUIPMENT.	827	2 042	43	11	7	17	-	2	2	-	-
517	HARDWARE, PLUMBING & HEATING EQUIPM.	2 842	6 997	174	31	36	55	25	7	-	2	-
5172	HARDWARE.	613	1 485	40	8	14	7	8	2	-	1	-
5174	PLUMBING AND HEATING EQUIPMENT.	1 492	3 872	82	15	13	21	5	3	-	1	-
5175	AIR CONDITIONING AND REFRIGERATION.	717	1 640	52	8	9	7	6	-	-	-	-
518	MACHINERY, EQUIPMENT, AND SUPPLIES.	10 941	31 [illegible]	516	145	119	127	85	34	13	4	1
5182	COMMERCIAL MACHINES AND EQUIPMENT.	3 214	10 [illegible]	97	26	25	19	13	7	5	1	-
5183	CONSTRUCTION AND MINING MACHINERY.	1 805	4 [illegible]	54	16	5	15	4	6	3	-	-
5184	FARM MACHINERY AND EQUIPMENT.	342	815	9	1	1	2	1	-	2	-	-
5185	INDUSTRIAL MACHINERY & EQUIPMENT.	3 [illegible]	9 [illegible]	154	45	47	52	15	5	-	-	-
5186	INDUSTRIAL SUPPLIES.	1 [illegible]	3 [illegible]	74	19	17	11	17	2	2	-	-
5187	PROFESSIONAL EQUIPMENT AND SUPPLIES.	1 [illegible]	3 [illegible]	44	14	14	7	14	5	-	-	-
5188	VENDING ESTABLISHMENT EQUIPMENT.	1 [illegible]	2 [illegible]	11	14	10	18	17	4	-	1	-
5189	TRANSPORTATION EQUIPMENT & SUPPLIES.		[illegible]	12	4	-	4	-	-	-	-	-
519	MISCELLANEOUS APPLIANCES.	10 [illegible]	34 [illegible]	772	205	157	173	124	46	25	5	-
5192	METALS & MINERALS, EXCEPT PETROLEUM.	1 [illegible]	4 [illegible]	44	20	2	11	11	5	-	-	-
5193	METALS, ORE AND METALS W PRODUCTS.	1 [illegible]	3 [illegible]	21	2	4	1	6	3	1	-	-
5194	SCRAP AND WASTE MATERIALS.	[illegible]	1 [illegible]	50	22	9	7	12	1	-	-	-
5195	TOBACCO AND ITS PRODUCTS.	[illegible]	[illegible]	5	4	1	-	1	1	-	-	-
5196	MISC. MISC. AND ELECTRICAL MACHINERY.	1 [illegible]	1 [illegible]	10	4	2	-	4	1	-	-	-
5198	PAPER AND ITS PRODUCTS.	2 [illegible]	6 [illegible]	135	30	24	24	21	5	1	-	-
5199	FURNITURE AND HOME FURNISHINGS.	1 [illegible]	3 [illegible]	97	34	22	28	12	3	1	-	-
5198	LUMBER AND CONSTRUCTION MATERIALS.	3 [illegible]	8 [illegible]	[illegible]	17	27	32	17	8	-	1	-
5999	MERCHANDISE, N.E.C.	4 [illegible]	11 [illegible]	470	92	80	84	10	8	1	1	-
--	ADMINISTRATIVE AND AUXILIARY.	4 [illegible]	12 [illegible]	82	10	17	13	6	6	6	1	-
[illegible]	RETAIL TRADE.	60 [illegible]	115 [illegible]	3 270	1 [illegible]	624	716	361	147	71	19	10
52	BUILDING MATERIALS & FARM EQUIPMENT.	1 [illegible]	3 [illegible]	170	10	24	28	14	6	1	1	-
521	LUMBER AND OTHER BUILDING MATERIALS.	1 [illegible]	2 [illegible]	91	8	9	21	8	3	-	1	-
523	PAINT, GLASS, AND WALLPAPER STORES.	[illegible]	[illegible]	18	8	1	3	1	1	-	-	-
524	ELECTRICAL SUPPLY STORES.	[illegible]	[illegible]	9	-	2	2	2	-	-	-	-
525	HARDWARE AND FARM EQUIPMENT.	[illegible]	[illegible]	50	14	9	9	3	1	-	-	-
526	[illegible] STORES.	[illegible]	47	32	14	4	8	1	1	-	-	-
53	GENERAL MERCHANDISE.	24 [illegible]	74 [illegible]	147	44	45	31	17	7	14	3	7
531	DEPARTMENT STORES.	15 [illegible]	20 [illegible]	15	-	-	-	5	-	4	2	5
532	MAIL ORDER HOUSES.		[illegible]	8	1	-	2	-	-	-	-	2
533	VARIETY STORES.	1 [illegible]	1 [illegible]	24	7	6	4	1	-	4	-	-
534	MERCHANDISE MACHINE OPERATORS.	[illegible]	1 [illegible]	14	6	2	4	3	1	1	-	-
539	[illegible] ORGANIZATIONS.	[illegible]	1 [illegible]	27	8	1	9	2	2	3	-	-
539	MISC. GENERAL MERCHANDISE STORES.	[illegible]	[illegible]	75	17	7	11	6	2	2	-	-
54	FOOD STORES.	5 [illegible]	5 [illegible]	3[illegible]	183	67	40	41	16	3	1	1
541	GROCERY STORES.	5 [illegible]	5 [illegible]	2[illegible]	116	42	30	33	21	3	1	1
542	MEAT AND FISH (SEA FOOD) MARKETS.	[illegible]	117	16	12	2	3	1	-	-	-	-
543	DAIRY PRODUCTS STORES.	[illegible]	[illegible]	18	7	4	4	-	-	-	-	-
546	RETAIL BAKERIES.	142	145	14	4	3	4	4	-	-	-	-
549	MISCELLANEOUS FOOD STORES.	[illegible]	118	12	5	4	2	1	-	-	-	-
55	AUTOMOTIVE DEALERS & SERVICE STATIONS.	9 [illegible]	18 [illegible]	8[illegible]	2[illegible]	2[illegible]	110	34	35	15	1	1
551	NEW AND USED CAR DEALERS.	3 [illegible]	10 [illegible]	42	4	-	3	10	25	10	-	-
552	USED CAR DEALERS.	[illegible]	[illegible]	34	14	10	7	2	1	-	-	-
553	TIRE, BATTERY, AND ACCESSORY DEALERS.	1 [illegible]	2 [illegible]	74	21	24	13	4	8	2	-	1
554	GASOLINE SERVICE STATIONS.	3 [illegible]	3 [illegible]	4[illegible]	18[illegible]	1[illegible]	74	18	3	2	1	-
559	MISC. AUTOMOTIVE DEALERS.	[illegible]	[illegible]	27	2	12	13	-	-	1	-	-
5599	AUTOMOTIVE DEALERS, N.E.C.	[illegible]	[illegible]	14	-	6	7	-	-	1	-	-
56	APPAREL AND ACCESSORY STORES.	4 [illegible]	6 [illegible]	3[illegible]	77	94	87	37	11	4	2	-
561	MENS & BOYS CLOTHING & FURNISHINGS.	1 [illegible]	1 [illegible]	78	16	18	20	10	3	-	1	-
562	WOMENS READY-TO-WEAR STORES.	1 [illegible]	2 [illegible]	92	25	19	21	15	6	2	1	-
563	WOMENS ACCESSORY & SPECIALTY STORES.	[illegible]	[illegible]	15	5	2	5	1	-	-	-	-
565	FAMILY CLOTHING STORES.	[illegible]	[illegible]	18	4	7	6	1	-	1	-	-
566	SHOE STORES.	1 [illegible]	1 [illegible]	94	20	41	26	6	2	1	-	-
57	FURNITURE AND HOME FURNISHINGS STORES.	2 [illegible]	6 [illegible]	2[illegible]	91	89	62	17	5	2	1	-
571	FURNITURE AND HOME FURNISHINGS.	1 [illegible]	3 [illegible]	1[illegible]	54	47	37	13	5	1	-	-
5712	FURNITURE STORES.	1 [illegible]	3 [illegible]	10[illegible]	33	30	22	11	4	1	1	-
5713	FLOOR COVERING STORES.	113	210	23	12	6	5	-	-	-	-	-
5716	DRAPERY AND UPHOLSTERY STORES.	126	143	7	2	2	-	1	1	-	-	-
5719	MISC. HOME FURNISHINGS STORES.	141	169	18	4	6	7	1	-	-	-	-
572	HOUSEHOLD APPLIANCE STORES.	[illegible]	[illegible]	21	9	6	4	1	-	1	-	-
573	RADIO, TELEVISION, AND MUSIC STORES.	[illegible]	[illegible]	61	22	15	21	3	-	-	-	-
5732	RADIO AND TELEVISION STORES.	[illegible]	[illegible]	27	7	7	10	3	-	-	-	-
5733	MUSIC STORES.	200	294	34	15	8	11	-	-	-	-	-
58	EATING AND DRINKING PLACES.	18 [illegible]	16 [illegible]	605	159	119	181	145	55	23	4	3

Fig. C-2. Counties: 1973 - Fulton County (Continued)

TABLE 2. Counties: 1973—Continued

SIC code	Industry	Number of employees, mid-March pay period	Taxable payroll, first qtr. ($1,000)	Total reporting units	Number of reporting units, by employment size class: 1 to 3	4 to 7	8 to 19	20 to 49	50 to 99	100 to 249	250 to 499	500 or more
	FULTON--CON.											
59	MISCELLANEOUS RETAIL STORES	8 590	9 771	766	323	224	159	65	9	6	-	-
591	DRUG STORES AND PROPRIETARY STORES	1 659	2 244	108	25	23	42	13	2	3	-	-
592	LIQUOR STORES	1 077	1 647	212	88	87	35	2	-	-	-	-
593	ANTIQUE STORES AND SECONDHAND STORES	563	679	46	25	8	7	5	-	1	-	-
594	BOOK AND STATIONERY STORES	315	433	40	21	9	4	5	1	-	-	-
5942	BOOK STORES	119	145	22	12	6	3	1	-	-	-	-
5943	STATIONERY STORES	196	288	18	9	3	1	4	1	-	-	-
595	SPORTING GOODS STORES & BICYCLE SHOPS	120	205	22	14	4	3	1	-	-	-	-
5952	SPORTING GOODS STORES	101	101	20	14	3	2	1	-	-	-	-
596	FARM AND GARDEN SUPPLY STORES	337	495	22	8	5	5	3	-	1	-	-
597	JEWELRY STORES	486	974	81	13	17	5	2	4	-	-	-
599	RETAIL STORES, N.E.C.	1 869	2 017	248	120	62	49	16	2	1	-	-
5992	FLORISTS	341	472	62	29	18	13	2	-	-	-	-
5994	NEWS DEALERS AND NEWSSTANDS	100	123	8	4	1	2	-	1	-	-	-
5995	CAMERA & PHOTOGRAPHIC SUPPLY STORES	69	140	10	4	3	2	1	-	-	-	-
5997	GIFT, NOVELTY, AND SOUVENIR SHOPS	297	275	50	23	14	12	1	-	-	-	-
5999	MISCELLANEOUS RETAIL STORES, N.E.C.	671	1 796	103	54	22	17	8	1	1	-	-
--	ADMINISTRATIVE AND AUXILIARY	5 679	12 073	50	6	7	10	11	5	3	4	4
---	FINANCE, INSURANCE, AND REAL ESTATE	44 645	100 586	2 151	1 094	399	313	192	80	45	18	9
60	BANKING	11 062	24 198	27	-	2	4	7	4	2	2	6
601	FEDERAL RESERVE BANKS	101	101	2	-	-	-	-	-	-	1	1
602	COMMERCIAL AND STATE SAVINGS BANKS	101	101	22	-	1	2	7	4	2	1	5
61	CREDIT AGENCIES OTHER THAN BANKS	6 732	10 085	290	91	75	46	29	14	7	2	-
611	MORTGAGE AND FINANCING INSTITUTIONS	101	101	2	-	-	-	-	2	-	-	-
612	SAVINGS AND LOAN ASSOCIATIONS	973	2 174	10	-	-	3	3	1	1	2	-
614	PERSONAL CREDIT INSTITUTIONS	2 255	4 012	174	62	61	26	15	6	4	-	-
615	BUSINESS CREDIT INSTITUTIONS	974	2 318	55	22	6	10	10	3	1	-	-
616	LOAN CORRESPONDENTS AND BROKERS	177	299	7	2	2	1	-	2	-	-	-
62	SECURITY, COMMODITY BROKERS & SERVICES	2 229	8 135	79	27	12	15	16	2	4	1	-
621	SECURITY BROKERS AND DEALERS	1 784	7 198	60	21	8	13	13	1	3	1	-
623	SECURITY AND COMMODITY EXCHANGES	101	101	1	-	-	-	-	-	1	-	-
628	SECURITY AND COMMODITY SERVICES	101	101	15	5	2	2	3	1	-	-	-
63	INSURANCE CARRIERS	12 982	31 429	226	55	28	38	46	26	20	10	3
631	LIFE INSURANCE	5 951	15 858	117	30	12	20	31	12	8	4	2
632	ACCIDENT AND HEALTH INSURANCE	602	921	9	2	1	3	2	-	-	1	-
633	FIRE, MARINE, AND CASUALTY INSURANCE	6 094	13 519	67	10	6	9	11	12	13	5	1
635	SURETY INSURANCE	207	518	10	3	3	3	-	-	1	-	-
6352	BANK DEPOSIT INSURANCE	101	101	1	-	-	-	-	-	1	-	-
636	TITLE INSURANCE	174	384	10	2	4	2	1	1	-	-	-
639	INSURANCE CARRIERS, N.E.C.	96	177	11	7	2	1	-	1	-	-	-
64	INSURANCE AGENTS, BROKERS, & SERVICE	2 918	7 215	392	205	63	56	17	9	1	1	-
65	REAL ESTATE	9 218	16 878	1 112	667	204	137	74	21	8	2	-
651	REAL ESTATE OPERATORS AND LESSORS	4 348	8 322	581	359	112	62	38	6	4	-	-
653	AGENTS, BROKERS, AND MANAGERS	2 837	4 849	265	143	53	27	13	5	2	2	-
655	SUBDIVIDERS AND DEVELOPERS	1 134	2 252	121	59	20	25	14	3	-	-	-
656	OPERATIVE BUILDERS	861	1 476	74	38	10	14	8	3	1	-	-
66	COMBINED REAL ESTATE, INSURANCE, ETC.	500	1 455	34	16	8	5	2	1	2	-	-
67	HOLDING AND OTHER INVESTMENT COMPANIES	1 043	2 461	58	31	9	11	1	4	1	1	-
671	HOLDING COMPANIES	835	2 090	23	8	5	5	-	3	1	1	-
673	TRUSTS	110	181	13	7	4	1	-	1	-	-	-
---	SERVICES	83 [illegible]	131 [illegible]	5 127	2 338	1 216	891	377	162	92	31	18
70	HOTELS AND OTHER LODGING PLACES	7 860	8 168	138	45	29	17	22	7	12	2	4
701	HOTELS, TOURIST COURTS, AND MOTELS	7 585	7 943	83	11	14	13	20	7	12	2	4
702	ROOMING AND BOARDING HOUSES	83	72	18	14	2	1	1	-	-	-	-
703	TRAILER PARKS AND CAMPS	97	92	17	9	5	3	-	-	-	-	-
7031	TRAILER PARKS	85	85	12	8	3	1	-	-	-	-	-
704	MEMBERSHIP-BASIS ORGANIZATION HOTELS	94	77	18	10	7	-	1	-	-	-	-
72	PERSONAL SERVICES	5 175	6 583	588	257	175	111	29	12	3	-	1
721	LAUNDRIES AND DRY CLEANING PLANTS	2 716	3 390	167	50	52	41	11	9	3	-	1
7211	POWER LAUNDRIES,FAMILY & COMMERCIAL	120	128	13	2	5	5	1	-	-	-	-
7213	LINEN SUPPLY	837	1 324	4	-	-	1	1	1	1	-	1
7215	COIN-OPERATED LAUNDRIES & CLEANING	141	107	29	19	5	4	-	1	-	-	-
7216	DRY CLEANING PLANTS, EXCEPT RUG	1 073	1 052	107	27	39	29	8	4	-	-	-
7218	INDUSTRIAL LAUNDERERS	377	589	5	1	-	-	-	2	2	-	-
722	PHOTOGRAPHIC STUDIOS	289	368	37	17	11	6	2	1	-	-	-
723	BEAUTY SHOPS	1 221	1 576	223	103	71	40	9	-	-	-	-
724	BARBER SHOPS	132	153	15	45	8	2	-	-	-	-	-
725	SHOE REPAIR AND HAT CLEANING SHOPS	100	116	22	11	9	1	1	-	-	-	-
726	FUNERAL SERVICE AND CREMATORIES	261	477	26	5	8	11	1	1	-	-	-
727	GARMENT PRESSING, ALTERATION, REPAIR	27	22	15	14	-	1	-	-	-	-	-
729	MISCELLANEOUS PERSONAL SERVICES	241	324	21	6	7	4	4	-	-	-	-

Fig. C-2. Counties: 1973 - Fulton County (Continued)

TABLE 2 **Counties: 1973**—Continued

SIC code	Industry	Number of employees mid March pay period	Taxable payroll Jan.-Mar. ($1,000)	Total reporting units	Number of reporting units, by employment size class: 1 to 3	4 to 7	8 to 19	20 to 49	50 to 99	100 to 249	250 to 499	500 or more
	FULTON--CON.											
73	MISCELLANEOUS BUSINESS SERVICES	29 015	30 849	803	300	183	150	74	47	26	16	7
731	ADVERTISING	992	2 887	114	62	27	17	4	3	1	-	-
7311	ADVERTISING AGENCIES	778	2 238	82	42	19	14	3	3	1	-	-
7313	RADIO, TV, PUBLISHER REPS.	101	201	22	15	3	-	-	-	-	-	-
732	CREDIT REPORTING AND COLLECTION	870	1 470	47	9	11	16	6	2	1	-	-
733	DUPLICATING, MAILING, STENOGRAPHIC	924	980	62	17	12	8	3	1	1	-	-
7331	DIRECT MAIL ADVERTISING	124	206	4	5	-	2	-	1	-	-	-
7332	BLUEPRINTING AND PHOTOCOPYING	283	574	13	3	5	-	3	-	1	-	-
7334	STENOGRAPHIC AND DUPLICATING NEC	215	220	22	9	4	6	-	-	-	-	-
734	SERVICES TO BUILDINGS	5 [illegible]	5 871	100	28	20	20	10	5	3	6	2
7342	DISINFECTING AND EXTERMINATING	[illegible]	101	23	7	4	8	2	1	-	1	-
7349	MISCELLANEOUS SERVICES TO BUILDINGS	4 [illegible]	5 [illegible]	76	20	22	12	7	4	3	5	2
736	PRIVATE EMPLOYMENT AGENCIES	1 [illegible]	2 240	64	17	14	14	5	1	2	1	-
739	MISCELLANEOUS BUSINESS SERVICES	16 [illegible]	20 [illegible]	611	154	89	70	42	34	18	8	5
7391	BUSINESS CONSULTING SERVICES	2 [illegible]	6 [illegible]	103	88	30	23	15	11	2	1	-
7393	DETECTIVE AND PROTECTIVE SERVICES	2 [illegible]	3 [illegible]	56	6	6	7	7	5	5	2	1
7394	EQUIPMENT RENTAL AND LEASING	867	1 [illegible]	55	15	5	10	5	1	1	-	-
7395	PHOTOFINISHING LABORATORIES	472	742	14	4	3	2	1	3	1	-	-
7397	COMMERCIAL TESTING LABORATORIES	142	193	5	-	-	4	-	1	-	-	-
7398	TEMPORARY HELP SUPPLY SERVICE	4 [illegible]	[illegible]	27	3	-	1	3	4	7	4	3
7399	BUSINESS SERVICES, N.E.C.	3 [illegible]	4 [illegible]	110	38	32	15	12	8	2	2	1
75	AUTO REPAIR, SERVICES & GARAGES	3 [illegible]	6 [illegible]	390	160	85	73	22	12	4	-	-
751	AUTOMOBILE RENTALS, WITHOUT DRIVERS	1 [illegible]	2 [illegible]	60	13	5	9	8	2	3	-	-
7512	PASSENGER CAR RENTAL AND LEASING	[illegible]	1 [illegible]	22	7	4	5	2	1	2	-	-
7513	TRUCK RENTAL AND LEASING	[illegible]	1 [illegible]	16	2	1	4	6	-	1	-	-
752	AUTOMOBILE PARKING	[illegible]	820	32	12	4	4	6	4	1	-	-
7523	PARKING LOTS	[illegible]	761	24	8	4	3	4	4	1	-	-
753	AUTOMOBILE REPAIR SHOPS	1 [illegible]	2 [illegible]	255	119	66	49	4	4	-	-	-
7531	TOP AND BODY REPAIR SHOPS	223	[illegible]	36	13	10	10	1	-	-	-	-
7534	TIRE RETREADING AND REPAIR SHOPS	523	[illegible]	20	9	2	4	-	3	-	-	-
7535	PAINT SHOPS	[illegible]	1[illegible]	10	5	5	4	-	-	-	-	-
7538	GENERAL AUTOMOBILE REPAIR SHOPS	5[illegible]	8[illegible]	98	50	26	16	2	1	-	-	-
7539	AUTOMOBILE REPAIR SHOPS, N.E.C.	3[illegible]	6[illegible]	67	37	21	12	1	-	-	-	-
754	AUTOMOBILE SERVICES, EXCEPT REPAIR	3[illegible]	3[illegible]	55	15	4	9	4	1	-	-	-
7542	AUTOMOBILE LUBRICATION	2[illegible]	2[illegible]	22	9	2	7	2	2	-	-	-
76	MISCELLANEOUS REPAIR SERVICES	1 [illegible]	3 [illegible]	173	82	38	37	10	3	3	-	-
762	ELECTRICAL REPAIR SHOPS	5[illegible]	5[illegible]	47	27	6	10	1	2	1	-	-
7622	RADIO AND TELEVISION REPAIR	1[illegible]	4[illegible]	70	21	4	4	-	1	1	-	-
7629	ELECTRICAL REPAIR SHOPS, N.E.C.	2[illegible]	5[illegible]	11	4	-	4	1	1	1	-	-
763	WATCH, CLOCK, AND JEWELRY REPAIR	[illegible]	1[illegible]	12	6	2	4	-	-	-	-	-
764	REUPHOLSTERY AND FURNITURE REPAIR	1[illegible]	2[illegible]	25	13	6	4	1	-	-	-	-
769	MISCELLANEOUS REPAIR SHOPS	[illegible]	2 [illegible]	83	32	22	18	8	1	2	-	-
7692	WELDING REPAIR	[illegible]	[illegible]	6	1	3	1	-	-	1	-	-
7694	ARMATURE REWINDING SHOPS	[illegible]	[illegible]	13	5	1	5	1	-	1	-	-
7699	REPAIR SERVICES, N.E.C.	[illegible]	1 [illegible]	60	26	18	12	3	1	-	-	-
78	MOTION PICTURES	1 [illegible]	1 [illegible]	91	27	17	35	11	6	-	-	-
781	MOTION PICTURE PRODUCTION AND DISTRIBUTION	[illegible]	1 [illegible]	44	14	9	17	4	1	-	-	-
7812	MOTION PICTURE PRODUCTION	[illegible]	[illegible]	19	9	1	4	-	-	-	-	-
7814	MOTION PICTURE FILM EXCHANGES	[illegible]	[illegible]	15	1	-	9	2	-	-	-	-
783	MOTION PICTURE THEATERS	[illegible]	[illegible]	42	6	8	16	7	5	-	-	-
7832	THEATERS, EXCEPT DRIVE-IN	[illegible]	[illegible]	34	6	7	11	6	4	-	-	-
79	AMUSEMENT AND RECREATION SERVICES, NEC	1 [illegible]	2 [illegible]	191	49	39	28	15	9	2	-	-
791	DANCE HALLS, STUDIOS, AND SCHOOLS	[illegible]	[illegible]	18	7	4	3	3	-	-	-	-
792	PROFESSIONAL ORCHESTRAS, ENTERTAINERS	[illegible]	[illegible]	43	16	15	9	3	-	-	-	-
7922	THEATRICAL PRODUCERS AND SERVICES	[illegible]	[illegible]	18	6	6	5	1	-	-	-	-
7929	ENTERTAINERS & ENTERTAINMENT GROUPS	[illegible]	[illegible]	21	9	6	4	2	-	-	-	-
793	BOWLING AND BILLIARD ESTABLISHMENTS	[illegible]	[illegible]	15	10	-	3	2	-	-	-	-
794	MISC. AMUSEMENT, RECREATION SERVICES	1 [illegible]	2 [illegible]	92	15	18	10	7	4	2	-	-
7941	SPORTS PROMOTERS, ATHLETIC FIELDS	[illegible]	1 [illegible]	8	-	2	1	2	-	1	-	-
7947	GOLF COURSES AND COUNTRY CLUBS	[illegible]	[illegible]	9	2	1	-	3	2	1	-	-
7949	AMUSEMENT AND RECREATION, N.E.C.	[illegible]	[illegible]	22	8	6	6	-	2	-	-	-
80	MEDICAL AND OTHER HEALTH SERVICES	12 [illegible]	2[illegible]	1 [illegible]	600	273	116	28	20	6	8	8
801	OFFICES OF PHYSICIANS AND SURGEONS	2 [illegible]	6 [illegible]	591	347	168	63	11	2	-	-	-
802	OFFICES OF DENTISTS, DENTAL SURGEONS	1 [illegible]	2 [illegible]	316	207	84	24	1	-	-	-	-
804	OFFICES OF CHIROPRACTORS	31	28	23	22	1	-	-	-	-	-	-
806	HOSPITALS	5 [illegible]	9 [illegible]	14	1	-	1	1	3	1	3	4
807	MEDICAL AND DENTAL LABORATORIES	781	1 [illegible]	54	19	13	13	6	2	1	-	-
8071	MEDICAL LABORATORIES	623	911	16	6	3	1	4	1	1	-	-
8072	DENTAL LABORATORIES	358	749	38	13	10	12	2	1	-	-	-
809	HEALTH AND ALLIED SERVICES, N.E.C.	2 353	2 [illegible]	88	40	7	14	9	13	4	1	-
8092	SANATORIA CONVALESCENT & REST HOMES	1 724	1 [illegible]	30	3	2	5	6	9	4	1	-
8099	HEALTH & ALLIED SERVICES, N.E.C.	628	1 087	57	36	5	9	3	4	-	-	-
81	LEGAL SERVICES	2 680	5 809	346	217	59	39	21	4	6	-	-

Fig. C-2. Counties: 1973 - Fulton County (Continued)

TABLE 2. Counties: 1973—Continued

(Excludes government employees, railroad employees, self-employed persons, etc. See General Explanation. See cols. 1 to 3 establishments reporting units having payroll during 1st quarter but no employees during mid-March pay period. "D" denotes figure withheld to avoid disclosure of operations of individual reporting units)

SIC code	Industry	Number of employees, mid-March pay period	Taxable payroll, Jan. 1 to Dec. 31 ($1,000)	Total reporting units	Number of reporting units, by employment size class: 1 to 3	4 to 7	8 to 19	20 to 49	50 to 99	100 to 249	250 to 499	500 or more
	FULTON--CON.											
82	EDUCATIONAL SERVICES	5 [illegible]	[illegible]	246	83	53	56	30	[illegible]	7	5	-
821	ELEMENTARY AND SECONDARY SCHOOLS	2 [illegible]	[illegible]	167	49	48	37	18	-	3	2	-
822	COLLEGES AND UNIVERSITIES	1 771	1 565	16	2	-	3	4	2	2	3	-
824	CORRESPONDENCE AND VOCATIONAL SCHOOLS	493	944	21	14	2	8	4	3	-	-	-
8242	VOCATIONAL SCHOOLS	476	892	27	14	-	6	4	3	-	-	-
829	SCHOOLS & EDUCATIONAL SERVICES, NEC	671	820	71	16	2	6	4	1	2	-	-
86	NONPROFIT MEMBERSHIP ORGANIZATIONS	8 685	12 596	615	258	164	123	59	17	11	2	1
861	BUSINESS ASSOCIATIONS	679	1 481	102	58	26	16	2	1	1	-	-
862	PROFESSIONAL ORGANIZATIONS	229	523	21	12	4	3	1	-	1	-	-
863	LABOR ORGANIZATIONS	695	1 187	46	49	20	19	6	-	-	-	-
864	CIVIC AND SOCIAL ASSOCIATIONS	1 244	1 607	87	42	21	24	4	4	2	-	-
866	RELIGIOUS ORGANIZATIONS	2 704	2 747	310	65	59	92	27	8	-	1	-
867	CHARITABLE ORGANIZATIONS	1 502	2 502	38	7	7	4	10	2	5	1	-
869	NONPROFIT MEMBER ORGANIZATIONS, NEC	1 585	2 311	39	16	8	3	7	2	2	-	1
89	MISCELLANEOUS SERVICES	7 471	20 410	521	217	121	102	57	16	10	1	1
891	ENGINEERING & ARCHITECTURAL SERVICES	4 371	12 618	249	85	64	50	34	8	7	-	1
892	NONPROFIT RESEARCH AGENCIES	399	637	27	9	8	7	3	2	-	-	-
893	ACCOUNTING, AUDITING, AND BOOKKEEPING	2 392	7 249	187	88	40	36	13	6	3	1	-
899	SERVICES, N.E.C.	203	526	37	22	8	5	2	-	-	-	-
--	ADMINISTRATIVE AND AUXILIARY	101	101	22	6	3	6	2	2	2	1	-
...	UNCLASSIFIED ESTABLISHMENTS	1 083	1 620	234	139	57	33	5	-	-	-	-
	GILMER											
	TOTAL	2 433	3 185	147	73	32	23	9	3	6	1	-
...	AGRICULTURAL SERVICES,FORESTRY,FISHERIES	(D)	(D)	3	1	-	1	1	-	-	-	-
...	CONTRACT CONSTRUCTION	8a	104	15	8	4	2	1	-	-	-	-
...	MANUFACTURING	1 663	2 188	27	6	5	4	3	3	5	1	-
20	FOOD AND KINDRED PRODUCTS	(D)	(D)	4	-	-	-	-	-	1	1	-
201	MEAT PRODUCTS	(D)	(D)	2	-	-	-	-	-	1	1	-
2015	POULTRY DRESSING PLANTS	(D)	(D)	2	-	-	-	-	-	1	1	-
22	TEXTILE MILL PRODUCTS	836	1 124	4	1	-	1	3	-	4	-	-
227	FLOOR COVERING MILLS	843	849	6	-	-	1	2	-	3	-	-
2273	WOVEN CARPETS AND RUGS	(D)	(D)	2	-	-	-	1	-	1	-	-
2279	TUFTED CARPETS AND RUGS	(D)	(D)	2	-	-	-	1	-	2	-	-
229	YARN AND THREAD MILLS	(D)	(D)	2	1	-	-	-	-	1	-	-
2281	YARN MILLS, EXCEPT WOOL	(D)	(D)	1	-	-	-	-	-	1	-	-
24	LUMBER AND WOOD PRODUCTS	134	147	8	1	3	1	-	2	-	-	-
...	TRANSPORTATION AND OTHER PUBLIC UTILITIES	(D)	(D)	3	2	-	1	-	-	-	-	-
...	WHOLESALE TRADE	46	91	7	4	2	-	1	-	-	-	-
...	RETAIL TRADE	286	333	61	34	14	11	1	-	-	-	-
55	AUTOMOTIVE DEALERS & SERVICE STATIONS	63	102	17	14	1	2	-	-	-	-	-
...	FINANCE, INSURANCE, AND REAL ESTATE	71	214	4	1	1	1	1	-	-	-	-
...	SERVICES	202	242	21	12	6	3	1	-	1	-	-
80	MEDICAL AND OTHER HEALTH SERVICES	156	165	6	1	2	1	1	-	1	-	-
806	HOSPITALS	(D)	(D)	1	-	-	-	-	-	1	-	-
...	UNCLASSIFIED ESTABLISHMENTS	15	10	6	5	1	-	-	-	-	-	-
	GLASCOCK											
	TOTAL	312	328	21	11	4	2	3	-	1	-	-
...	CONTRACT CONSTRUCTION	(D)	(D)	2	1	1	-	-	-	-	-	-
...	MANUFACTURING	194	221	5	1	1	1	1	-	1	-	-
23	APPAREL AND OTHER TEXTILE PRODUCTS	(D)	(D)	1	-	-	-	-	-	1	-	-
232	MEN'S AND BOYS' FURNISHINGS	(D)	(D)	1	-	-	-	-	-	1	-	-
2327	MEN'S & BOYS' SEPARATE TROUSERS	(D)	(D)	1	-	-	-	-	-	1	-	-
...	RETAIL TRADE	71	45	10	6	2	1	1	-	-	-	-
...	FINANCE, INSURANCE, AND REAL ESTATE	(D)	(D)	2	2	-	-	-	-	-	-	-
...	SERVICES	(D)	(D)	2	1	-	-	1	-	-	-	-
	GLYNN											
	TOTAL	19 910	27 103	1 077	448	276	224	78	24	20	6	3
...	AGRICULTURAL SERVICES,FORESTRY,FISHERIES	73	65	22	14	6	2	-	-	-	-	-
09	FISHERIES	36	27	15	12	2	1	-	-	-	-	-

Fig. C-2. Counties: 1973 - Fulton County (Continued)

No. 11. Population—States: 1960 to 1973

[Population in thousands. [illegible] as of July 1, [illegible] as indicated. Includes Armed Forces stationed in area. [illegible] For [illegible] population, 1920 to 1970, see table 13. Minus sign (-) denotes decrease]

STATE	1960	1965	1969	1970	1971	1972	1973 POPULATION (prov.): Rank order	1973 POPULATION (prov.): Total	1973 POPULATION (prov.): Per sq. mile of land area	AVERAGE ANNUAL PERCENT CHANGE: Apr. 1, 1950–Apr. 1, 1960	AVERAGE ANNUAL PERCENT CHANGE: Apr. 1, 1960–Apr. 1, 1970	AVERAGE ANNUAL PERCENT CHANGE: Apr. 1, 1970–July 1, 1973
U.S.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(X)	209,851	59	1.7	1.3	1.0
N.E.	10,532	11,329	[illegible]	11,842	12,024	12,105	(X)	12,151	193	1.2	1.2	0.8
Maine	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.6	0.3	1.1
N.H.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.3	1.9	2.1
Vt.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	48	464	[illegible]	0.3	1.3	1.3
Mass.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	743	0.9	1.0	0.7
R.I.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.8	1.0	0.6
Conn.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3	1.8	0.4
M.A.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	37,621	(X)	37,529	374	1.2	0.8	0.3
N.Y.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.2	0.8	(Z)
N.J.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3	1.7	0.8
Pa.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.8	0.4	0.3
E.N.C.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(X)	[illegible]	[illegible]	1.8	1.1	0.5
Ohio	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.2
Ind.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.1	0.7
Ill.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.0	[illegible]
Mich.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.1	1.3	0.6
Wis.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.5	1.1	1.0
W.N.C.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(X)	[illegible]	33	0.9	0.6	0.7
Minn.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.4	1.1	[illegible]
Iowa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.6
Mo.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.5
N.Dak.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.2	[illegible]	1.1
S.Dak.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.4	-0.2	0.8
Nebr.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.6	0.5	1.2
Kans.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.3	0.3	0.4
S.A.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31,923	(X)	32,459	122	2.0	1.7	1.7
Del.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.4	2.1	1.5
Md.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	411	[illegible]	2.4	1.1
D.C.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.1	-0.4
Va.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.8	1.6	1.1
W.Va.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.9
N.C.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.2	1.1	1.1
S.C.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.2	0.8	1.0
Ga.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	14	[illegible]	[illegible]	1.4	1.5	1.3
Fla.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.2	3.8
E.S.C.	[illegible]	[illegible]	[illegible]	[illegible]	12,999	13,156	(X)	13,289	74	0.5	0.6	1.1
Ky.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.3	0.6	1.2
Tenn.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4,120	[illegible]	0.8	1.0	1.5
Ala.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.6	0.5	0.8
Miss.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2,281	48	(Z)	0.2	0.9
W.S.C.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19,482	(X)	20,257	47	1.5	1.3	1.4
Ark.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.7	0.7	1.8
La.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	84	1.9	1.1	1.0
Okla.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.4	[illegible]	1.2
Tex.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]	[illegible]	1.6	1.6
Mt.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(X)	9,149	11	3.0	1.9	3.1
Mont.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	43	[illegible]	[illegible]	1.3	0.3	1.2
Idaho	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42	[illegible]	[illegible]	1.2	0.7	2.4
Wyo.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	1.3	0.1	1.5
Colo.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.3	3.0
N.Mex.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3.3	0.7	2.6
Ariz.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	18	5.5	3.1	4.6
Utah	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	36	[illegible]	14	2.6	1.7	2.7
Nev.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	47	[illegible]	[illegible]	[illegible]	5.4	3.5
Pac.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	(X)	[illegible]	[illegible]	3.4	2.2	1.6
Wash.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22	[illegible]	[illegible]	1.8	1.8	0.2
Oreg.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31	[illegible]	[illegible]	1.5	1.7	[illegible]
Calif.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	4.0	2.4	[illegible]
Alaska	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	5.6	[illegible]	[illegible]
Hawaii	642	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	40	[illegible]	[illegible]	2.4	2.0	2.4

X Not applicable. Z Less than 0.05 percent.
[illegible] see table 2[illegible].

Source: U.S. Bureau of the Census, *Current Population Reports*, series P-25, Nos. [illegible] and unpublished data.

Fig. C-3. Population-States: 1960 to 1973

Table 52

(Data based on sample, see text. For maximum error for derived figures (percent, median, etc.) and meaning of symbols, see text.)

The State Urban and Rural, Rural Nonfarm, and Occupied Rural Farm	The State					The State—Percent distribution				
			Rural					Rural		
	Total	Urban	Total	Nonfarm	Occupied farm	Total	Urban	Total	Nonfarm	Occupied farm
Total population	4 589 575	2 766 584	1 822 991	1 569 455	253 529					
All housing units	1 470 942	896 042	574 900	500 083	74 817	100.0	100.0	100.0	100.0	100.0
Vacant—seasonal and migratory	3 855	294	3 561	3 561		0.3	-	0.6	0.7	
All year-round housing units	1 466 087	896 333	569 754	496 467	74 017	100.0	100.0	100.0	100.0	100.0
POPULATION										
Population in housing units, 1970	4 402 765	2 656 870	1 745 895	1 502 136	243 759					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
Population in housing units, 1960	3 866 255	2 133 119	1 733 136	1 521 177	212 959					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					
TENURE, RACE, AND VACANCY STATUS										
All occupied units	1 344 233	847 144	525 037	447 370	74 017	93.4	94.7	91.5	90.2	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	229 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	15 636	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	102 627	[illegible]	9 753	24.2	[illegible]	19.0	19.7	13.2
[illegible]	[illegible]	[illegible]	49 056	[illegible]	5 504	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Vacant year-round units	61 463	49 318	44 447	44 447		4.6	5.3	8.1	9.8	
[illegible]	[illegible]	[illegible]	4 [illegible]	4 [illegible]		[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]						
With complete plumbing facilities	10 [illegible]	7 644	3 551	3 551		0.1	0.8	0.6	[illegible]	
[illegible]	43 [illegible]	39 [illegible]	13 [illegible]	13 [illegible]		2.9	3.2	2.4	[illegible]	
[illegible]	[illegible]	[illegible]	8.4	9.3						
With complete plumbing facilities	23 [illegible]	26 [illegible]	1 [illegible]	1 [illegible]		[illegible]	2.9	[illegible]	[illegible]	
Rented or sold, awaiting occupancy	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
Held for seasonal use	18 [illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
Other vacant	6 [illegible]	5 [illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	
All year-round housing units	1 466 087	896 333	570 754	496 467	74 017	100.0	100.0	100.0	100.0	100.0
PLUMBING FACILITIES										
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PIPED WATER IN STRUCTURE										
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
None	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FLUSH TOILET										
For exclusive use of household	1 328 [illegible]	873 [illegible]	454 [illegible]	394 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Also used by another household	6 870	6 [illegible]	766	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
None	[illegible]	16 424	115 262	101 [illegible]	[illegible]	[illegible]	[illegible]	20.2	20.4	[illegible]
BATHTUB OR SHOWER										
For exclusive use of household	1 308 [illegible]	857 308	451 007	390 [illegible]	60 [illegible]	89.2	95.7	79.1	78.1	81.0
Also used by another household	6 332	5 580	752	715	38	0.4	0.6	0.1	0.1	0.1
None	152 029	33 335	118 694	105 140	13 564	10.4	3.7	20.8	21.2	18.3
COMPLETE KITCHEN FACILITIES										
All year-round units	1 466 087	896 333	570 754	496 467	74 017	100.0	100.0	100.0	100.0	100.0
For exclusive use of household	1 343 441	864 524	478 917	414 121	64 796	91.6	96.5	83.9	83.4	87.5
Also used by another household	1 771	1 643	128	120	8	0.1	0.2	[illegible]	[illegible]	[illegible]
No complete kitchen facilities	121 475	30 036	91 439	82 226	9 213	8.3	3.4	16.0	16.6	12.4
Renter occupied	533 798	289 879	151 859	136 343	15 505	100.0	100.0	100.0	100.0	100.0
For exclusive use of household	466 278	261 633	104 645	94 645	10 000	87.5	94.9	68.9	69.4	64.5
Also used by another household	1 324	1 245	79	79		0.2	0.3	0.1	0.1	
No complete kitchen facilities	65 116	17 993	47 123	41 621	5 504	12.2	4.7	31.0	30.5	35.5
ACCESS										
With direct access	1 466 033	895 646	570 387	496 374	74 013	100.0	99.9	100.0	100.0	100.0
Lacking direct access	694	587	97	93	4	-	0.1	-	-	-
TELEPHONE										
All occupied units	1 369 733	847 188	522 037	446 020	76 017	100.0	100.0	100.0	100.0	100.0
Are other	1 [illegible]	1 844	38[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
None	2[illegible]	344	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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Fig. C-4. Occupancy, Utilization, and Plumbing Characteristics for the State: 1970

Table 37 Fuels and Appliances for the State: 1970

(Data based on sample, see text. For meaning of symbols, see text)

The State
Inside and Outside Standard Metropolitan Statistical Areas
Urban and Rural, Rural Nonfarm, and Occupied Rural Farm

	The State	Inside SMSA's	Outside SMSA's	Urban	Rural: Total	Rural: Nonfarm	Rural: Occupied farm
All year-round housing units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BEDROOMS							
All year-round units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Owner occupied	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Renter occupied	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ELEVATOR IN STRUCTURE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
All occupied housing units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HOUSE HEATING FUEL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WATER HEATING FUEL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
COOKING FUEL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CLOTHES WASHING MACHINE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DISHWASHER	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HOME FOOD FREEZER	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TELEVISION	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BATTERY OPERATED RADIO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
OWNED SECOND HOME	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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Fig. C-5. Fuels and Appliances for the State: 1970

Table 60. **Occupancy, Utilization, and Plumbing Characteristics for Counties: 1970**—Continued

[Data based on sample, see text. For minimum base for derived figures (percent, median, etc.) and meaning of symbols, see text]

Counties / Rural / Occupied Rural Farm	Floyd			Forsyth			Franklin			Fulton		
	Total	Rural	Occupied rural farm	Total	Rural	Occupied rural farm	Total	Rural	Occupied rural farm	Total	Rural	Occupied rural farm
Total population	73 742	37 149	3 883	16 928	16 928	3 068	12 784	12 784	1 535	607 592	46 962	3 104
All housing units	24 093	11 653	866	6 063	6 063	786	4 387	4 387	499	287 016	12 335	1 817
Vacant—seasonal and migratory	19	19					28	28		37	10	
All year-round housing units	24 074	11 6[illegible]	866	6 063	6 063	786	4 369	4 369	499	287 779	12 325	1 817
POPULATION												
Population in housing units	71 918	35 932	2 834	16 189	16 189	2 710	12 649	12 649	1 571	586 387	46 061	3 436
Per occupied unit	3.1	3.2	[illegible]	3.1	3.1	3.5	3.1	3.1	3.1	3.0	3.5	3.4
Owner	3.1	3.2	3.2	3.2	3.4	3.3	3.0	3.0	3.2	3.2	3.5	3.2
Renter	3.1	3.5	3.8	3.5	3.5	4.2	3.4	3.4	3.0	2.7	3.1	4.1
TENURE, RACE, AND VACANCY STATUS												
Owner occupied	16 693	8 727	[illegible]	4 923	4 923	684	3 772	3 772	457	91 387	9 [illegible]	613
White	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Negro	[illegible]	[illegible]								[illegible]	[illegible]	
Renter occupied	8 291	2 741	[illegible]	1 213	1 213	102	1 26[illegible]	1 26[illegible]	42	107 1[illegible]8	2 614	[illegible]
White	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42	[illegible]	[illegible]	[illegible]
Negro	[illegible]	[illegible]	4				242	[illegible]		[illegible]	[illegible]	[illegible]
Vacant year-round	1 090	136		817	817		331	331		16 224	377	
For sale only	[illegible]	80		[illegible]			[illegible]				[illegible]	
Vacant less than 6 months	[illegible]	[illegible]					[illegible]	[illegible]			214	
Median price asked	$12 900	$11 600		$[illegible]	$[illegible]		$11 500	$11 500		$[illegible]	$14 [illegible]	
For rent	417	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
Vacant less than 2 months	291	[illegible]		[illegible]	[illegible]		41	41		[illegible]	[illegible]	
Median rent asked	$58	$51					$[illegible]	$[illegible]		$[illegible]	$[illegible]	
Other vacant	660	287		80	80		140	140		[illegible]	155	
PLUMBING FACILITIES												
With all plumbing facilities	22 [illegible]	[illegible]	745	5 [illegible]	5 [illegible]	710	3 470	3 470	405	[illegible]	[illegible]	889
Lacking some or all plumbing facilities	2 302	1 4[illegible]	[illegible]	4[illegible]5	4[illegible]5	76	891	891	94	[illegible]	[illegible]	128
Lacking only hot water	[illegible]	128	[illegible]	60	60	4	76	76		[illegible]	[illegible]	6
Lacking other plumbing facilities	1 807	1 363	121	821	821	72	817	817	94	[illegible]	[illegible]	122
PIPED WATER IN STRUCTURE												
Hot and cold	22 [illegible]	[illegible]	778	5 188	5 188	746	3 [illegible]	3 [illegible]	4[illegible]	[illegible]	[illegible]	902
Cold only	864	534	38	613	613	23	354	354	5	787	472	37
None	698	671	50	235	235	4	352	352	27	64[illegible]	432	80
FLUSH TOILET												
For exclusive use of household	22 707	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	897
Also used by another household	81	[illegible]								[illegible]	[illegible]	
None	1 286	1 207	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	120
BATHTUB OR SHOWER												
For exclusive use of household	22 313	10 312	757	5 242	5 242	729	3 580	3 580	405	[illegible]	[illegible]	903
Also used by another household	61	[illegible]					13	13		[illegible]	[illegible]	
None	1 659	1 282	109	750	750	57	776	776	94	[illegible]	[illegible]	[illegible]
COMPLETE KITCHEN FACILITIES												
For exclusive use of household	22 963	10 772	816	5 687	5 687	776	3 958	3 958	[illegible]	[illegible]	[illegible]	928
Also used by another household	[illegible]			5	5					945	5	
No complete kitchen facilities	1 096	892	50	307	307	10	461	461	23	1 158	559	89
ROOMS												
1 room	127	40		26	26		13	13		3 272	30	
2 rooms	416	133	3	81	87		56	56		9 083	96	5
3 rooms	2 439	793	32	526	526	17	173	173	10	31 590	471	55
4 rooms	5 4[illegible]	3 023	109	1 824	1 824	135	1 [illegible]	1 [illegible]	86	49 [illegible]	[illegible]	146
5 rooms	[illegible]	4 522	263	1 832	1 832	309	1 [illegible]	1 [illegible]	[illegible]	[illegible]	[illegible]	207
6 rooms	4 850	2 520	244	1 100	1 100	184	978	978	[illegible]	[illegible]	[illegible]	248
7 rooms	1 730	677	93	405	405	102	316	316	50	8 [illegible]	[illegible]	196
8 rooms or more	1 169	386	48	203	203	39	213	213	40	9 [illegible]	2 213	162
Median, all units	4.9	4.9	5.3	4.8	4.8	5.3	5.0	5.0	5.6	4.8	5.0	5.9
Median, owner occupied units	5.3	5.1	5.4	5.0	5.0	5.3	5.2	5.2	5.6	6.0	6.2	6.2
Median, renter occupied units	4.2	4.4	4.9	4.4	4.4	5.0	4.[illegible]	4.5	5.9	3.9	4.5	4.4
PERSONS												
All occupied units	22 984	11 468	866	5 136	5 136	786	4 038	4 038	499	197 555	11 634	1 817
1 person	3 330	1 140	27	480	480	96	573	573	31	40 160	958	82
2 persons	6 991	3 392	322	1 533	1 533	217	1 235	1 235	172	56 956	3 153	357
3 persons	4 510	2 259	185	1 023	1 023	164	817	817	119	35 115	2 257	176
4 persons	3 871	2 031	184	1 008	1 008	167	756	756	91	26 088	2 455	152
5 persons	2 238	1 207	88	599	599	107	354	354	40	16 802	1 554	130
6 persons	1 106	599	73	303	303	49	178	178	26	8 841	774	49
7 persons	533	289	20	122	122	32	54	54	4	6 585	383	50
8 persons or more	405	181	15	58	58	11	123	123	10	2 976	170	21
Median, all occupied units	2.8	2.9	3.0	3.0	3.0	3.2	2.8	2.8	2.8	2.5	3.3	2.9
Median, owner occupied units	2.8	2.9	2.9	3.0	3.0	3.1	2.7	2.7	2.8	2.8	3.3	2.8
Median, renter occupied units	2.6	3.1	3.1	3.2	3.2	3.9	2.8	2.8	2.8	2.2	3.2	3.4
PERSONS PER ROOM												
All occupied units	22 984	11 468	866	5 136	5 136	786	4 038	4 038	499	197 555	11 634	1 817
1.00 or less	20 878	9 970	802	4 633	4 633	713	3 671	3 671	485	175 723	10 907	[illegible]
1.01 to 1.50	1 513	778	43	411	411	68	295	295	14	13 027	533	49
1.51 or more	593	320	21	82	82	5	72	72		4 705	214	41
With all plumbing facilities	21 296	9 828	745	4 363	4 363	710	3 285	3 28[illegible]	405	192 847	10 556	889
1.00 or less	19 544	8 599	[illegible]	4 [illegible]	4 152	[illegible]	3 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	846
1.01 to 1.50	1 236	657	32	[illegible]	[illegible]	56	214	[illegible]		[illegible]	[illegible]	32
1.51 or more	416	174		9	30	5	[illegible]	[illegible]		[illegible]	[illegible]	10

Fig. C-6. Occupancy, Utilization, and Plumbing Characteristics for Counties: 1970

Table 63 **Fuels and Appliances for Counties: 1970** – Continued

[Data based on sample; see text. For meaning of symbols, see text]

Counties Rural Occupied Rural Farm	Reno			Forsyth			Franklin			Fulton		
	Total	Rural	Occupied rural farm	Total	Rural	Occupied rural farms	Total	Rural	Occupied rural farm	Total	Rural	Occupied rural farms
All year-round housing units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BEDROOMS												
All year-round units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
None	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
1	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4 or more	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Owner-occupied	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
None and 1	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5 or more	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Renter-occupied	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
None	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
1	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
2	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
3 or more	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
All occupied housing units	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HOUSE HEATING FUEL												
Utility gas	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fuel oil, kerosene, etc.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
Coal or coke	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wood	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Electricity	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bottled, tank, or LP gas	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other fuel	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
None	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
WATER HEATING FUEL												
Utility gas	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
Fuel oil, kerosene, etc.	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
Coal or coke	[illegible]									[illegible]	[illegible]	
Wood	[illegible]	[illegible]								[illegible]		
Electricity	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bottled, tank, or LP gas	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other fuel										[illegible]	[illegible]	
None	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
COOKING FUEL												
Utility gas	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Electricity	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Bottled, tank, or LP gas	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fuel oil, kerosene, etc.	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	
Coal or coke	[illegible]						[illegible]	[illegible]		[illegible]	[illegible]	
Wood	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
Other fuel										[illegible]	[illegible]	[illegible]
None							[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
CLOTHES WASHING MACHINE												
Mangle or wringer	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Automatic or semiautomatic	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
None	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CLOTHES DRYER												
Electric	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other than electric	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
None	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
DISHWASHER												
Yes	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
No	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HOME FOOD FREEZER												
Yes	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
No	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TELEVISION												
Black and white	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Color	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
None	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Yes	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
No	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BATTERY OPERATED RADIO												
Yes	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
No	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
OWNED SECOND HOME												
Yes												

Fig. C-7. Fuels and Appliances for Counties: 1970

APPENDIX D

COUNTY X PLANNING DATA

The following information was distilled from data supplied by the Atlanta Regional Commission (ARC). Some of the information has been adjusted for the purposes of the County X illustration in this manual; therefore, this data should not be construed as official output from ARC. Instead, it is intended to illustrate the type of planning information which might be available for an air quality analysis. The text is written in the format that might be used by a planning group to present its results.

D.1. INTRODUCTION

The Regional Planning Commission is now completing an economic base study of the seven-county region. The attached documents are an advance release of the major assumptions and the major variables contained in the study. They consist of regional projections of employment, population, and income.

These major assumptions and variables were approved by the Regional Planning Commission and they are now ready for use as inputs to the regional development planning process and for all other purposes for which such projections are needed. The Commission is engaged in examining alternative policies for regional development. Distribution of socio-economic activities below the regional level will differ depending upon which set of alternative policies is finally adopted.

D.2. PRINCIPAL ASSUMPTIONS

The following are the principal assumptions underlying the recommended projections of growth for the Commission Planning Area for 1970 to 2000.

1. That the free enterprise system as it now exists will remain as national policy throughout the forecast period.
2. That employment in the United States will rise by approximately 46 million jobs (64.8%), and jobs in the Southeast will rise approximately 10 million (107.4%) between 1970 and 2000.
3. That there will be no public policy constraining the migration of workers from one part of the country to another to seek or accept job opportunities.
4. That the environmental amenities of the Region will not deteriorate significantly when compared to other urban areas of the country, and, therefore, people will not be deterred from moving to this region to take advantage of available employment opportunities.
5. That the Region's share of Southeastern employment will continue to increase more or less in line with 1950-1970 trends, meaning that employment will rise from approximately 621,000 in 1970 to 1,500,000 in 2000 (154.2%).
6. That the Region's specialty, when compared with the national profile, will continue to be wholesale trade, followed by transportation, communications, and utilities, finance, insurance, and real estate.
7. That the cornerstone of future growth in the Region rests on employment growth--i.e., long term population growth is contingent on employment opportunities. Population is expected to increase from one million 437 thousand in 1970 to approximately three million 479 thousand in 2000 (142.1%). Employment will grow slightly faster than population due primarily to increases in labor force participation rates.
8. That the projections contained in this Economic Base Study represent the growth potential of the seven-county area--i.e., in the regional

development planning process all of the projected growth will be distributed within the seven-county area. Any growth which may occur in peripheral counties (within new or existing towns) will be incremental to that projected for the planning district.

D.3. GROWTH PROJECTIONS

The following tables outline the Regional Planning Commission's projections for the area. Table D-1 contains employment projections, Table D-2 deals with population, and Table D-3 evaluates household size. Table D-4 gives employment projections for the Regional Planning Area.

Table D-1 Preliminary Non-farm Wage and Salary Employment Projections, 1960-2000

Year	Employment (000)		
	Most Likely	High	Low
1960	373.1	373.1	373.1
1970	621.4	621.4	621.4
1975	725.9	768.6	710.4
1980	859.9	940.7	809.4
1985	1,010.7	1,122.6	918.3
1990	1,183.1	1,319.4	1,042.2
1995	1,370.6	1,566.2	1,191.1
2000	1,579.8	1,863.0	1,365.0

Table D-2 Preliminary Population Projections, 1960-2000

Year	Population (000) Most Likely	High	Low
1960	1,044.5	1,044.5	1,044.5
1970	1,437.0	1,437.0	1,437.0
1975	1,710.1	1,758.0	1,621.6
1980	1,991.3	2,129.3	1,827.6
1985	2,321.4	2,513.9	2,052.1
1990	2,687.2	2,933.0	2,297.9
1995	3,074.9	3,451.2	2,599.4
2000	3,478.5	4,081.4	2,951.0

Table D-3 Preliminary Household Size Projections, 1950-2000

Year	Household Size (Persons/household)
1950	3.49
1960	3.42
1970	3.18
1975	2.99
1980	2.92
1985	2.89
1990	2.86
1995	2.84
2000	2.83

Table D-4 Civilian Non-farm Wage and Salary Employment, 1970-2000
Regional Planning Commission Area
Employment (in thousands)

Industry	RPCA 1970	1980	1990	2000
Manufacturing	123.8	152.9	214.7	291.9
Government	95.8	129.0	174.9	230.6
Services	94.3	143.8	205.3	284.0
Retail Trade	103.4	148.0	198.5	257.3
Wholesale Trade	66.3	93.9	128.6	170.1
T.C.U.[1]	59.4	82.1	109.2	142.6
F.I.R.E.[2]	45.0	64.3	90.1	122.8
Construction	32.6	45.1	60.9	79.5
Mining	.8	.8	.9	1.0
Total	621.4	859.9	1,183.1	1,579.8

[1]Transportation, Communication, and Utilities

[2]Finance, Insurance, and Real Estate

D.4. TRANSPORTATION POLICY DIRECTIONS

This section will briefly describe the transportation networks chosen for the regional development plan alternative directions. These directions present a "bracketing" of transportation options. Orientations toward additional highways or rapid transit (beyond the approved MARTA system) defines one end bracket. Limiting transportation investments to the approved MARTA system and to providing arterials that will be needed to serve this rail system defines the other "bracketed" scale. Existing development controls were assumed for these initial alternative directions. However, in the process of updating the regional development plan, subsequent alternatives will include new or modified development controls.

D.4.1. Alternative Direction I - (Highway Orientation)

This alternative direction was designed to evaluate the implications of providing a transportation system with a realistic maximum number of new highways combined with a minimum of new transit lines. The incorporation of the MARTA referendum system was assumed to be the minimum transit improvement. The feeder bus system will be limited to serving this adopted system.

The new highways were basically those in the adopted AATS plan, without the Tollway and with a new location for the outer loop.

As shown on the alternative direction I maps (Fig. D-1), the outer loop is extended to the southern portions of the region and the entire loop is located outside of existing contiguous development. The purpose of this loop is not to relieve the interstate traffic, but to evaluate the impacts to undeveloped areas and to existing nodes of development, if this accessibility was provided.

The maps do not show the extensive arterial and collector street system for the entire region that will also be analyzed in this alternative.

D.4.2. Alternative Direction II - (Transit Orientation)

For this direction the specifications were to provide for a system emphasizing maximum transit with no new freeways. Limited highway improvements will be provided only to enhance the transit service.

The maps for this alternative direction (Fig. D-2) show that the north-south components of the system are composed of two adopted MARTA rail lines with extensions to the north-west, northeast, southwest, and southeast. In the east-west direction the referendum system is again used as a basis, with extensions to the West Line, Creek Branch, and the East Line. Also the busway is replaced by a rail line and extended to the Highway.

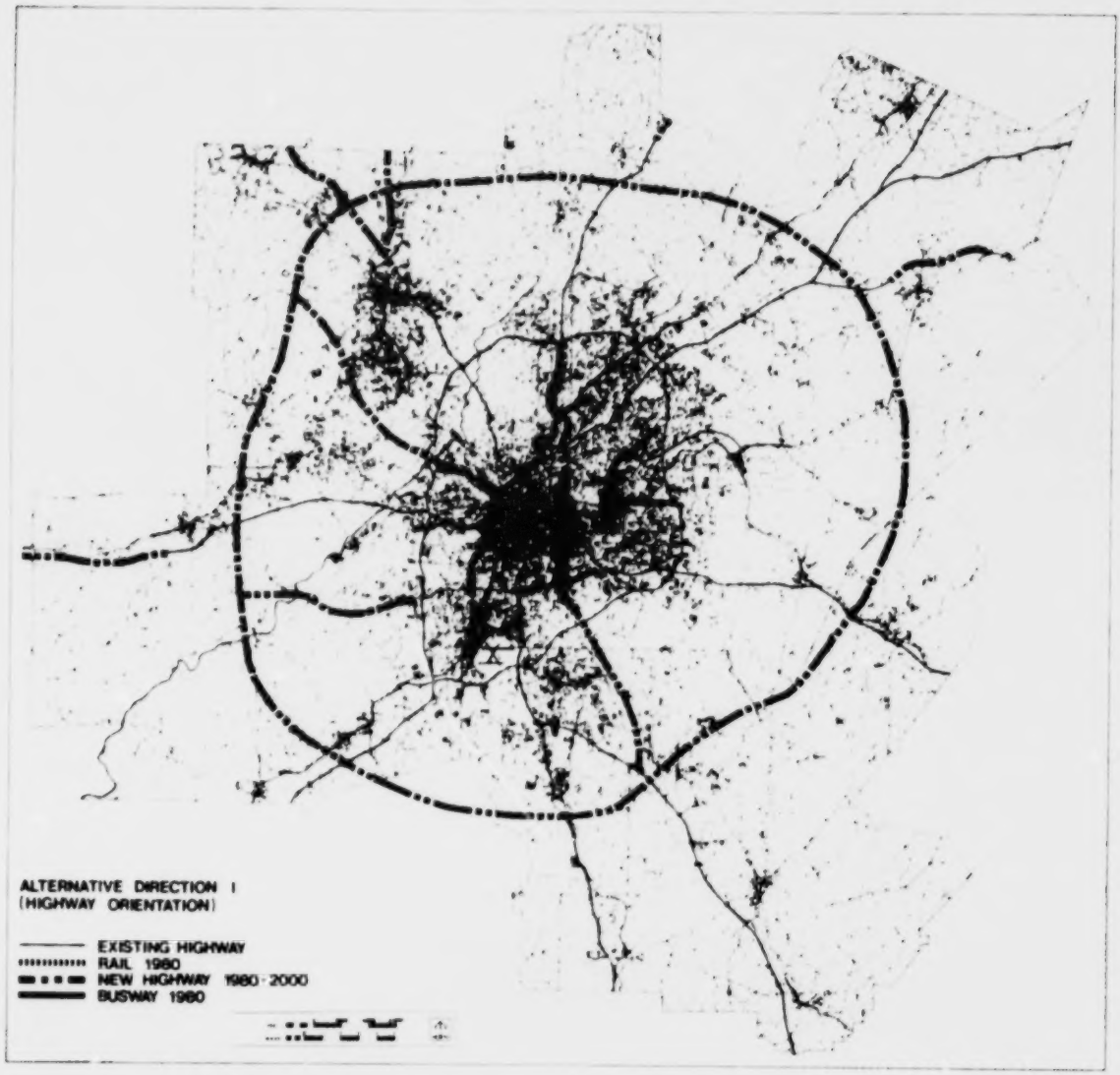

Fig. D-1. Alternative Transportation Direction I, Highway Orientation

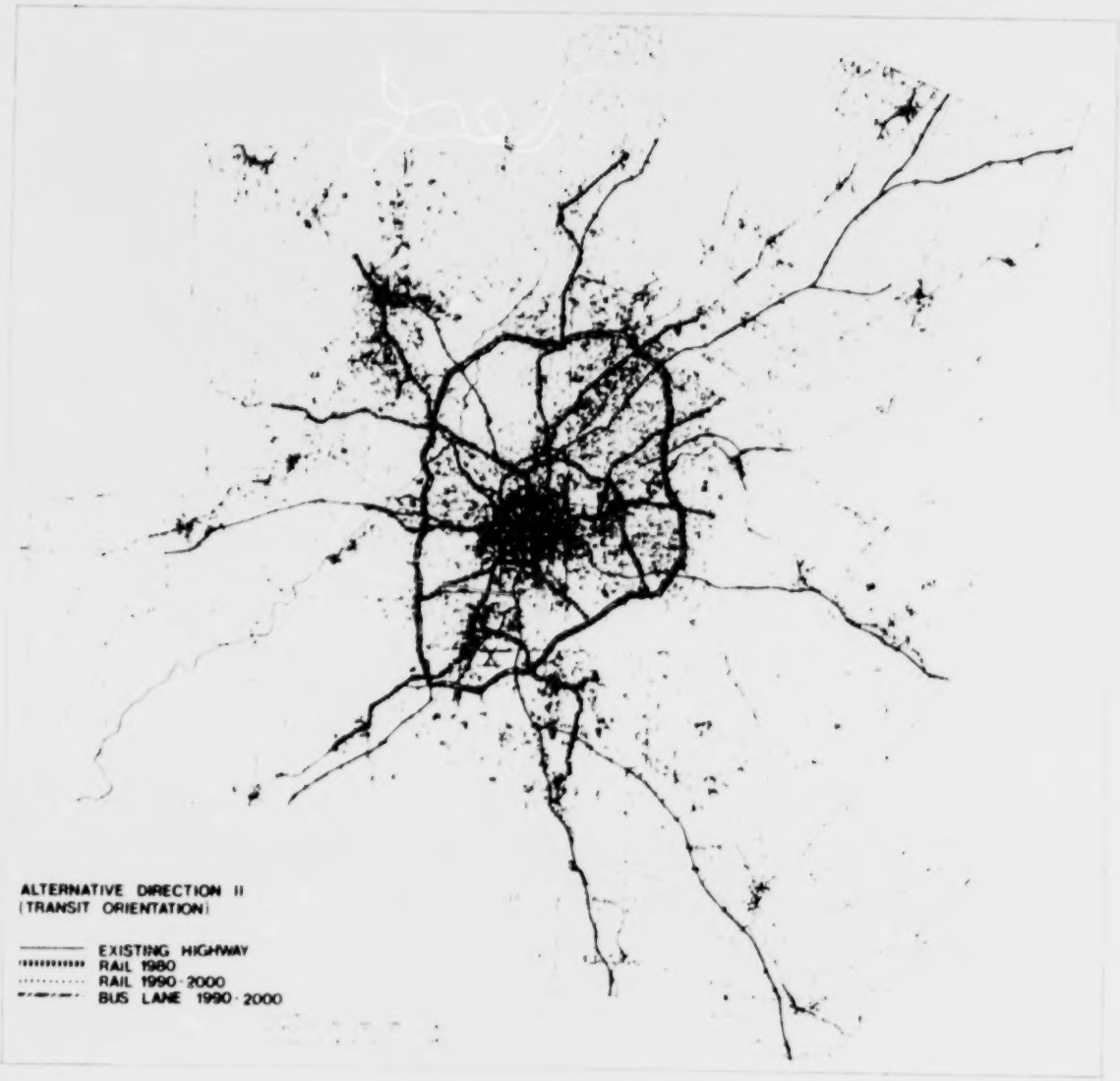

Fig. D-2. Alternative Transportation Direction II, Transit Orientation

There are two additional independent lines proposed in the system. One line runs south, skirting the east side of the downtown CBD, then turning west towards the Shopping Mall area. The other line provides service to the southeast.

There are no busways proposed in this system.

The criteria that was used in developing this alternative network was based on the following:

1. Transit service was generally provided to those areas of the region that were served by highways in direction I.
2. In order to minimize disruption to affected areas and reduce system costs, existing railroad rights-of-way were followed to the extent possible.
3. Operational characteristics necessary for a viable system were considered. This consisted of designing the system to facilitate ease of travel by reducing multiple transfers and to realistically distribute line loads.

Also, the maps do not show the extensive feeder bus system that will serve the region's rapid transit lines. This will be incorporated for analysis.

D.4.3. Alternative Direction III - (No new highways/adopted transit system)

This alternative direction was included to study the implications of a limited future transportation system for the region. This consisted of providing the adopted referendum transit system with no new highways. This "null" alternative will show (among other things) if and/or when transportation facilities in the region will become inadequate.

The map for this alternative (Fig. D-3) shows the location of these facilities in the seven county region.

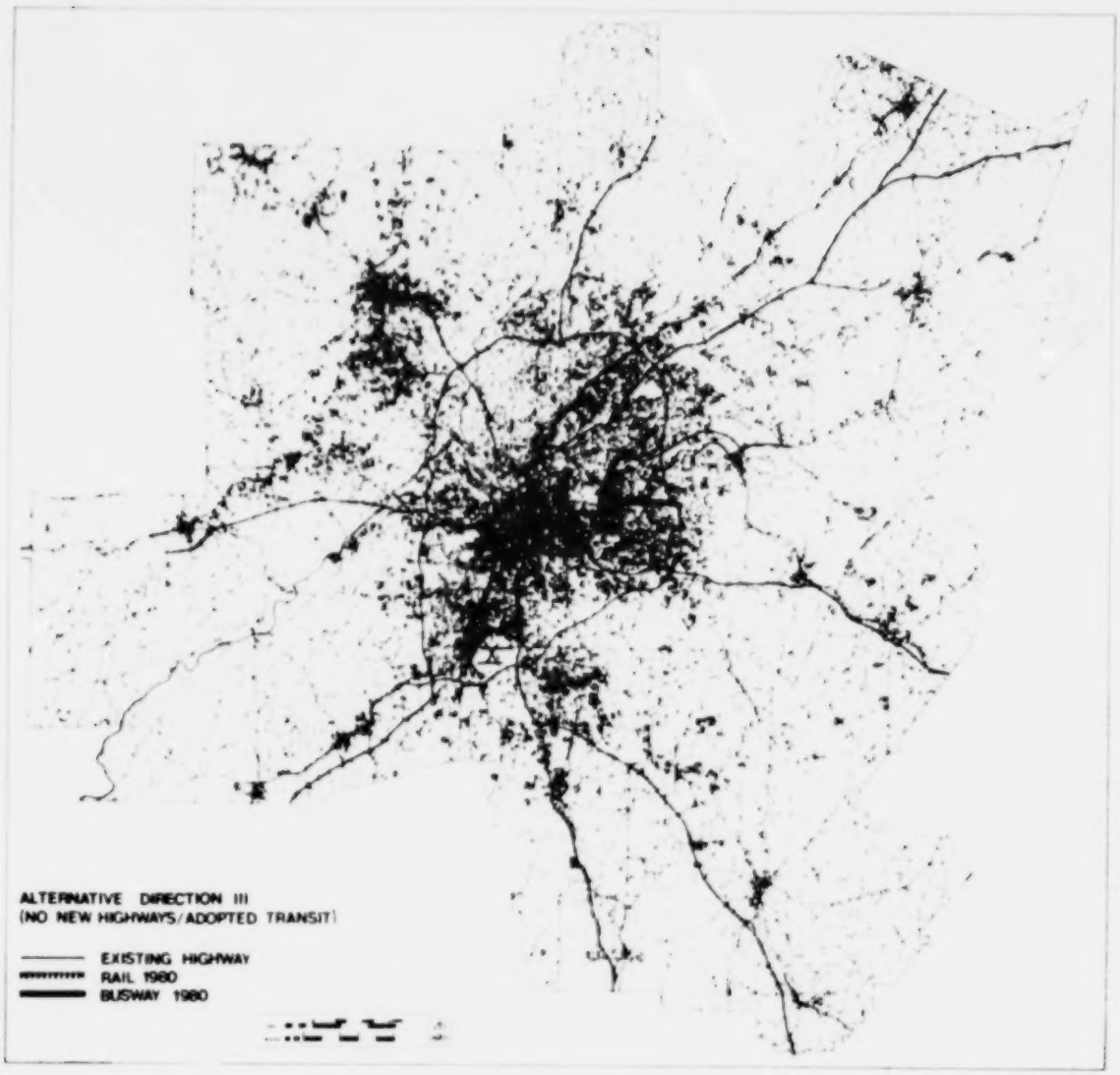

Fig. D-3. Alternative Transportation Direction III, No New Highways and Adopted Transit

D.5. LAND USE PROJECTIONS

Using the third transportation alternative (i.e., no new highways/ adopted transit) a set of land use projections was made using a simulation model. These results are tabulated on Tables D-5 to D-9.

Table D-5 lists the symbols and variables displayed on the computer printouts. Tables D-6, D-7, and D-8 give the land use projections for the 10 Superdistrict planning areas for 1970, 1980, and 1990, respectively. The Superdistricts are aggregations of census tracts. The same type of projection information is available on census tract resolution but is not presented here for brevity's sake. Table D-9 is a summary of industrial land use changes in each Superdistrict and is interpolated for 1973, which is the baseline in the County X analysis.

Table D-5 Legend for Computer Printouts

Variable Name	Parameter
TPOP	Total Population
TE-CON	Total Employment Minus Construction
THH	Total Households
%HIHH	Percent High Income Families/Total Households
%LIHH	Percent Low Income Families/Total Households
%MFHH	Percent Multifamily/Total Households
P0514	Population Ages 5 to 14
P1519	Population Ages 15 to 19
P65+	Population Older than 65
ULU	Amount of Land Used
NHHD	Net Household Density = THH/Residential Land
GHHD	Gross Household Density = THH/Total Land
NED	Net Employment Density
%RLU	Percent Residential Land Use
%CLU	Percent Commercial Land Use
%ILU	Percent Industrial Land Use
%ULU	Percent Used Land
%VAC	Percent Vacant Land (Usable)
P/R	Total Parks and Recreation Land
%P/POP	Percent Parks Land Per Person

Note: %VAC is just vacant usable land and does not include vacant land which is considered unsuitable for building; therefore, %VAC and %ULU do not add to 100%.

Table D-6. Land Use Projections for 1970

SUPERDISTRICTS AND COUNTIES AND CITY OF ATLANTA

1970

GENERAL DEMOGRAPHIC, EMPLOYMENT AND DEVELOPMENT MEASURES

	TPOP	TE-CON	THH	&HIHH	&LIHH	&MFHH	P0514	P1519	P65+	ULU	
	NHHD	GHHD	NED	&RLU	&CLU	&ILU	&OLU	&VAC	P/R	PR/MPOP	
*** SD 10 - CBD ATLANTA	5762.	91624.	2414.	2.33	31.14	92.79	719.	345.	1165.	595.	
	32.07	2.44	173.76	7.47	29.52	13.40	50.18	3.34	20.	3.49	
*** SD 11 - NE ATLANTA	72763.	83047.	28822.	11.13	23.17	36.31	8302.	4720.	9453.	5061.	
	10.43	3.72	33.93	35.48	13.33	10.20	65.31	7.20	504.	6.92	
*** SD 12 - NW ATLANTA	119833.	46409.	36793.	12.33	28.78	44.32	24455.	11041.	7444.	9169.	
	6.10	2.02	14.74	33.13	5.40	9.13	36.39	14.37	1160.	9.68	
*** SD 13 - SE ATLANTA	137575.	40737.	32478.	12.34	33.21	31.11	21743.	10331.	5704.	3495.	
	5.04	2.06	13.09	35.39	5.39	7.22	53.43	14.53	1037.	9.62	
*** SD 14 - SW ATLANTA	97854.	32381.	30265.	14.33	23.75	33.31	18674.	8099.	7040.	10669.	
	3.02	1.13	14.27	31.44	2.36	3.45	39.44	38.99	1469.	15.31	
*** SD 15 - TRI-CITIES	66553.	40673.	21963.	22.41	16.02	24.03	12157.	6111.	4932.	7403.	
	3.43	1.40	22.11	37.10	3.83	5.50	44.37	32.57	294.	4.42	
*** SD 16 - S FULTON	30784.	4697.	8487.	23.04	18.01	1.77	7118.	2742.	1958.	5718.	
	1.76	0.07	5.24	3.33	0.15	0.17	4.50	90.21	794.	25.73	
*** SD 17 - SOUTHEAST	45377.	30190.	17981.	41.02	5.64	39.03	6637.	3780.	6116.	11132.	
	1.74	1.15	27.97	64.35	4.17	0.80	71.26	13.44	539.	11.08	
*** SD 18 - SANDY SPGS	39542.	9459.	12600.	50.31	4.57	33.74	8009.	3534.	1598.	7222.	
	1.03	0.51	13.40	27.20	3.74	2.43	29.36	39.19	846.	21.33	
*** SD 19 - N FULTON	19132.	3062.	3740.	20.25	20.37	5.14	4055.	1339.	1531.	4743.	
	1.39	0.37	0.33	4.03	0.24	2.13	5.33	39.04	935.	40.03	

Table D-7. Land Use Projections for 1980

[illegible]

GENERAL DEMOGRAPHIC, EMPLOYMENT AND DEVELOPMENT MEASURES

TRAF	TE-COR	TMP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	P/R	PR/MPHR	

*** SD 10 - [illegible] ATLANTA

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*** SD 11 - SE ATLANTA

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*** SD 12 - SW ATLANTA

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*** SD 13 - SE ATLANTA

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*** SD 14 - SW ATLANTA

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*** SD 15 - TWI-CITIES

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*** SD 16 - S FULTON

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*** SD 17 - DEKALB

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*** SD 18 - [illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*** SD 19 - N FULTON

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table D-8. Land Use Projections for 1990

[illegible] ATLANTA

[illegible] 1990 53 [illegible]

GENERAL [illegible] MEASURES

	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
*** SD 10 = [illegible] ATLANTA																
	10545.	117154.	5331.	13.48	[illegible]	[illegible]	[illegible]	555.	620.	1500.	613.					
	56.58	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13.16	62.04	3.44	20.	1.90					
*** SD 11 = [illegible] ATLANTA																
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3153.	12044.	4431.						
	13.57	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	57.16	17.54	478.	7.85					
*** SD 12 = [illegible] ATLANTA																
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8483.	13396.	9814.					
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11.32	[illegible]	15.07	1178.	11.05					
*** SD 13 = [illegible] ATLANTA																
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15291.	7275.	11148.	8367.					
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	53.14	19.86	1199.	12.27					
*** SD 14 = [illegible] ATLANTA																
	128393.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20024.	8592.	13174.	13097.					
	[illegible]	1.74	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49.02	27.32	1705.	13.28					
*** SD 15 = TRI-CITIES																
	[illegible]	[illegible]	36213.	13.57	[illegible]	[illegible]	[illegible]	14339.	6843.	10555.	8553.					
	[illegible]	2.61	[illegible]	43.10	[illegible]	[illegible]	5.38	59.70	19.18	419.	4.57					
*** SD 16 = [illegible]																
	[illegible]	[illegible]	43733.	35.91	[illegible]	[illegible]	[illegible]	24579.	5787.	5880.	16241.					
	[illegible]	0.34	13.96	13.61	[illegible]	[illegible]	3.76	12.79	79.57	1832.	13.15					
*** SD 17 = [illegible]																
	[illegible]	[illegible]	25717.	[illegible]	[illegible]	[illegible]	[illegible]	6045.	3707.	9037.	11178.					
	2.67	1.65	[illegible]	61.64	[illegible]	1.42	71.55	12.90	534.	10.52						
*** SD 18 = [illegible]																
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12773.	5725.	6426.	11185.					
	[illegible]	1.51	[illegible]	[illegible]	[illegible]	[illegible]	1.23	[illegible]	33.66	2313.	27.27					
*** SD 19 = [illegible]																
	[illegible]	21711.	26077.	[illegible]	[illegible]	[illegible]	15512.	5950.	4441.	11303.						
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	79.43	1942.	23.23					

Table D-9. County X Industrial Land Use Change Calculations

Industrial Land Use Change Calculation: Fulton County Superdistricts

SD #	Name	% ILU	ILU (Acres)	Total Land Area	1973 ILU%	1980 ILU%	1990 ILU%	1973 ILU (Acre)	1975 ILU (Acre)	1980 ILU (Acre)	1985 ILU (Acre)	1990 ILU (Acre)	1975 ΔAREA	1980 ΔAREA	1985 ΔAREA
10	CBD Atlanta	60.18	595	989	13.40	13.36	13.16	133	132	132	131	130	(-0.002) -1/474	(-0.001) -1/948	(-0.001) -2/1622
11	NE Atlanta	65.31	5061	7749	10.26	8.71	9.53	795	735	675	707	738	(-0.126) -60/474	(-0.127) -120/948	(-0.054) -88/1622
12	NW Atlanta	50.39	9169	18196	9.15	10.18	11.32	1665	1759	1852	1956	2060	(0.198) 94/474	(0.197) 187/948	(0.179) 291/1622
13	SE Atlanta	53.96	8495	15743	7.22	7.40	7.82	1137	1151	1165	1198	1231	(0.030) 14/474	(0.030) 28/948	(0.038) 61/1622
14	SW Atlanta	39.94	10659	26713	3.48	4.05	4.80	930	1006	1082	1182	1282	(0.160) 76/474	(0.160) 152/948	(0.155) 252/1622
15	Tri-Cities	49.37	7403	14995	5.50	5.79	6.38	825	846	868	912	957	(0.044) 21/474	(0.045) 43/948	(0.054) 87/1622
16	South Fulton	4.50	5718	127067	0.17	0.49	0.76	216	420	623	795	966	(0.430) 204/474	(0.429) 407/948	(0.357) 579/1622
17	Buckhead Atlanta	71.26	11132	15622	0.80	1.07	1.42	125	146	167	195	222	(0.044) 21/474	(0.045) 42/948	(0.043) 70/1622
18	Sandy Springs	29.36	7222	24598	0.49	0.88	1.20	121	169	216	255	295	(0.101) 48/474	(0.100) 95/948	(0.147) 134/1622
19	North Fulton	5.38	4743	88160	0.10	0.23	0.51	88	145	203	326	450	(0.120) 57/474	(0.121) 115/948	(0.147) 238/1622
FULTON COUNTY TOTAL		20.66	70208	339832	1.78	2.06	2.45	6035	6509	6983	7657	8331	474	948	1622

D.6. OBERS GROWTH PROJECTIONS

Table D-10 gives the population, employment, personal income, and earnings projections developed by the Office of Business Economics (OBE), now the Bureau of Economic Affairs of the Department of Commerce, and the Economic Research Services (ERS) of the Department of Agriculture.

Table D-10. OBERS Growth Projections

A... AREA: METROPOLITAN ATLANTA
(A... CODE 056)

POPULATION, EMPLOYMENT, PERSONAL INCOME, AND EARNINGS BY INDUSTRY, HISTORICAL AND PROJECTED,
SELECTED YEARS, 1962 - 2000

	1962	1968	1969	1970	1975	1980	1985	1990	1995	2000
POPULATION, MIDYEAR	1,368,140	1,663,703	1,692,833	1,715,.74	1,911,000	2,129,000	2,373,600	2,646,400	2,898,300	3,174,200
PER CAPITA INCOME (1967$)*	2,872	3,231	3,436	3,510	4,149	4,786	5,415	6,124	7,116	8,269
PER CAPITA INCOME RELATIVE (US=1.00)	.96	.97	1.00	1.01	1.02	1.00	1.00	.99	1.00	1.00
TOTAL EMPLOYMENT						884,300	974,800	1,074,500	1,192,700	1,323,200
EMPLOYMENT/POPULATION RATIO	.00	.00				.42	.41	.41	.41	.42

IN THOUSANDS OF 1967 $

TOTAL PERSONAL INCOME *	3,382,398	5,374,671	5,816,310	6,020,460	7,929,200	10,144,400	12,853,100	16,205,200	20,824,700	26,269,300
TOTAL EARNINGS	2,906,873	4,653,750	5,055,905	5,189,930	6,607,100	8,411,400	10,518,900	13,154,400	16,816,700	20,995,200
AGRICULTURE, FORESTRY & FISHERIES	13,444>	14,766>	17,701>	12,849>	22,200	23,000	23,300	23,600	25,700	28,000
AGRICULTURE	30,233>	21,494>	27,377>	20,304>	21,300	21,900	22,100	22,300	24,200	26,200
FORESTRY & FISHERIES	390>	651>	611>	561>	900	1,000	1,100	1,300	1,500	1,700
MINING	193>	3,396>	3,445>	3,724>	8,700	10,300	12,300	14,600	17,600	21,200
METAL	>	>	>	>	100	200	200	300	400	500
COAL										
CRUDE PETROLEUM & NATURAL GAS	25>	5>	>	17>						
NONMETALLIC, EXCEPT FUELS	193>	7>	>	3,285>	8,500	10,000	11,900	14,200	17,100	22,500
CONTRACT CONSTRUCTION	162,309>	299,831>	325,466>	299,972>	390,500	508,400	630,800	782,600	982,400	1,232,900
MANUFACTURING	760,475>	1,109,816>	1,285,300>	1,204,211>	1,577,000	2,055,000	2,490,800	3,018,900	3,707,100	4,552,100
FOOD & KINDRED PRODUCTS	85,459>	140,456>	156,389>	115,146>	135,600	149,000	168,400	190,200	218,200	250,300
TEXTILE MILL PRODUCTS	110,177>	132,270>	130,873>	123,566>	177,100	224,800	259,100	298,600	348,000	405,600
APPAREL & OTHER FABRIC PRODUCTS	38,249>	59,559>	56,173>	56,475>	93,200	119,700	143,300	171,500	207,000	249,800
LUMBER PRODUCTS & FURNITURE	31,133>	42,009>	45,750>	43,740>	54,900	68,100	78,400	90,200	105,300	123,000
PAPER & ALLIED PRODUCTS	33,336>	43,596>	47,455>	44,488>	69,400	92,300	114,900	143,000	179,900	226,200
PRINTING & PUBLISHING	44,748>	73,642>	81,847>	81,622>	103,000	128,500	158,100	194,500	241,900	300,900
CHEMICALS & ALLIED PRODUCTS	24,553>	38,417>	42,104>	43,872>	59,700	76,800	94,400	116,200	144,700	180,100
PETROLEUM REFINING	1,307>	593>	365>	391>	2,700	3,700	4,500	5,400	6,600	8,000
PRIMARY METALS	496>	18,955>	19,044>	21,229>	53,700	63,000	74,600	88,400	104,900	124,400
FABRICATED METALS & ORDNANCE	25,488>	45,488>	49,339>	48,726>	73,800	102,700	132,600	171,200	222,200	288,300
MACHINERY, EXCLUDING ELECTRICAL	24,542>	38,504>	44,447>	37,761>	63,400	85,300	107,700	136,000	173,200	220,500
ELECTRICAL MACHINERY & SUPPLIES	14,443>	23,453>	28,372>	29,567>	57,000	77,800	104,100	139,300	186,200	248,700
MOTOR VEHICLES & EQUIPMENT	67,816>	116,342>	126,367>	112,449>	153,900	208,100	252,000	305,100	373,700	457,800
TRANS. EQUIP., EXCL. MTR. VEHS.	3,549>	35,267>	391>	32,088>	367,600	515,100	619,400	744,800	907,400	1,105,500
OTHER MANUFACTURING	44,477>	69,589>	77,347>	79,511>	107,600	139,700	176,700	223,600	284,600	362,300
TRANS., COMM. & PUBLIC UTILITIES	314,670	502,340	541,374	577,461	702,600	854,800	1,052,800	1,296,500	1,615,000	2,011,500
WHOLESALE & RETAIL TRADE	677,135	1,054,783	1,164,563	1,227,861	1,541,600	1,935,500	2,436,200	3,066,500	3,898,300	4,959,800
FINANCE, INSURANCE & REAL ESTATE	214,245	335,116	360,749	390,166	482,700	587,100	767,600	935,900	1,181,700	1,492,000
SERVICES	398,181	655,897	724,422	766,301	1,003,800	1,314,900	1,702,600	2,204,500	2,868,400	3,732,200
GOVERNMENT	363,346	599,181	619,255	648,918	875,200	1,111,400	1,418,900	1,810,600	2,316,700	2,964,200
CIVILIAN GOVERNMENT	332,954	542,431	567,455	620,861	807,900	1,051,500	1,350,100	1,733,700	2,229,000	2,866,000
ARMED FORCES	30,378	56,752	52,014	68,058	54,1[illegible]	[illegible]	68,200	76,900	86,900	98,100

APPENDIX E
COUNTY X FUEL USE DATA

This appendix contains fuel consumption data taken from reports prepared by the Bureau of Mines, U.S. Department of Interior, Washington, DC 20240. County X is assumed to be in the state of Georgia. The data included are the following:

1. From Mineral Industry Surveys, Sales of Fuel Oil and Kerosene in 1973

   Figure E-1. Sales of Kerosene in the United States (Table 5 in the Survey).

   Figure E-2. Sales of Distillate-type Heating Oils in the United States (Table 6 in the Survey).

   Figure E-3. Sales of Residual-type Heating Oils in the United States (Table 7 in the Survey).

   Figure E-4. Sales of Distillate-type and Residual-type Fuel Oils for Industrial Use (Excluding Oil Company Use) in the United States (Table 8 in the Survey).

   Figure E-5. Sales of Distillate-type and Residual-type Fuel Oils for Use by Oil Companies in the United States (Table 9 in the Survey).

   Figure E-6. Sales of Distillate-type and Residual-type Fuel Oils for Use by the Military in the United States (Table 12 in the Survey).

2. From Mineral Industry Surveys
   Coal-Bituminous and Lignite in 1973

   Figure E-7. Distribution of Bituminous Coal and Lignite (Table 42 of the Survey).

3. From Mineral Industry Surveys
   Natural Gas Production and Consumption: 1973

   Figure E-8. Quantity and Value of Natural Gas Delivered to Consumers. (Table 7 of the Survey)

Table 5.--Sales of Kerosine in the United States, by P.A.D. District, State, and Use: 1973 and 1972 1/

(Thousand barrels)

P.A.D. District and State	Heating		All other use 2/		Total	
	1973	1972	1973	1972	1973	1972
District I:						
New England, total	3,970	5,597	432	771	4,402	6,368
Connecticut	458	690	133	212	591	902
Maine	1,290	1,763	24	33	1,314	1,796
Massachusetts	1,161	1,687	186	391	1,347	2,078
New Hampshire	469	652	24	54	493	706
Rhode Island	201	345	29	38	230	383
Vermont	391	460	36	43	427	503
Delaware	341	383	20	33	361	416
District of Columbia	30	31	3	5	33	36
Florida	1,545	1,840	558	814	2,103	2,654
Georgia	121	153	208	293	329	446
Maryland	1,027	1,723	57	81	1,084	1,804
New Jersey	1,401	1,687	143	288	1,544	1,975
New York	5,646	6,938	300	792	5,946	7,730
North Carolina	7,180	8,443	475	1,085	7,655	9,528
Pennsylvania	3,673	4,868	302	618	3,975	5,486
South Carolina	1,758	2,032	82	179	1,840	2,211
Virginia	3,075	4,293	210	429	3,285	4,722
West Virginia	270	345	26	38	296	383
Total	30,037	38,333	2,816	5,426	32,853	43,759
District II:						
Illinois	3,147	2,985	1,338	1,332	4,485	4,317
Indiana	1,486	2,169	20	15	1,506	2,184
Iowa	384	358	157	148	541	506
Kansas	100	99	37	51	137	150
Kentucky	1,772	1,870	380	387	2,152	2,257
Michigan	1,540	2,089	455	556	1,995	2,645
Minnesota	844	915	28	55	872	970
Missouri	316	318	94	163	410	481
Nebraska	763	756	19	15	782	771
North Dakota	91	139	45	46	136	185
Ohio	3,697	3,721	1,146	1,270	4,843	4,991
Oklahoma	439	418	217	260	656	678
South Dakota	8	6	6	1	14	7
Tennessee	2,958	2,587	591	740	3,549	3,327
Wisconsin	1,459	1,472	40	61	1,499	1,533
Total	19,004	19,902	4,573	5,100	23,577	25,002
District III:						
Alabama	905	388	275	294	1,180	682
Arkansas	899	269	266	265	1,065	534
Louisiana	1,029	375	2,335	1,715	3,364	2,090
Mississippi	1,014	377	2,742	1,808	3,756	2,185
New Mexico	790	344	360	316	1,150	660
Texas	5,934	4,008	2,775	3,277	8,709	7,285
Total	10,471	5,761	8,753	7,675	19,224	13,436
District IV:						
Colorado	194	213	377	415	571	628
Idaho	207	180	92	125	299	305
Montana	84	77	321	306	405	383
Utah	181	196	180	182	361	378
Wyoming	219	237	130	131	349	368
Total	885	903	1,100	1,159	1,985	2,062
District V:						
Alaska	10	13	8	8	18	21
Arizona	47	53	43	50	90	103
California	680	1,039	238	106	918	1,145
Hawaii	25	35	16	17	41	52
Nevada	6	6	2	3	8	9
Oregon	15	38	76	79	91	117
Washington	92	116	18	32	110	148
Total	875	1,300	401	295	1,276	1,595
United States, total	61,272	66,199	17,643	19,655	78,915	85,854

1/ Excludes kerosine-type jet fuel.
2/ Includes kerosine used in lamps, tractors, cooking stoves, etc.

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Fig. E-1. Sales of Kerosene in the United States

Table 6.--Sales of Distillate-type Heating Oils in the United States, by P.A.D. District and State: 1973 and 1972

(Thousand barrels)

P.A.D. District and State	Heating Oils						
	1973					1972 1/	
	No. 1 Automatic burners	No. 1 Other heating	No. 2	No. 4	Total	No. 2	Total
District I							
New England, total	1,660	1,152	94,617	6,978	104,675	97,820	106,955
Connecticut	175	50	16,485	2,475	19,185	17,258	19,691
Maine	966	439	8,633	250	9,688	9,046	10,178
Massachusetts	648	125	50,797	3,738	55,508	52,100	56,439
New Hampshire	208	163	6,978	90	7,439	7,088	7,550
Rhode Island	85	113	7,203	171	7,572	7,705	8,122
Vermont	178	62	4,543	252	5,033	4,623	4,975
Delaware	199	20	2,944	29	3,192	3,252	3,492
District of Columbia	93	10	2,271	73	2,445	2,252	2,375
Florida	187	196	3,789	30	4,402	3,210	3,895
Georgia	101	77	2,803	3	2,984	2,766	2,967
Maryland	180	172	11,944	165	12,441	12,236	12,713
New Jersey	264	87	40,043	11,471	51,865	40,621	52,367
New York	1,695	159	78,476	12,312	92,692	80,036	94,108
North Carolina	683	462	10,257	140	11,542	10,678	11,710
Pennsylvania	965	185	39,161	5,872	44,161	38,807	44,648
South Carolina	251	127	3,082	20	3,480	3,190	3,858
Virginia	482	278	11,901	302	12,963	11,103	12,110
West Virginia	31	15	878	5	929	908	961
Total 1973	5,769	3,340	301,496	15,178	446,923	XXX	XXX
Total 1972	6,652	3,432	307,084	36,971	XXX	307,084	352,119
District II							
Illinois	2,066	620	18,827	280	22,343	19,073	23,213
Indiana	1,829	1,028	16,594	673	17,824	15,129	18,481
Iowa	1,199	432	4,579	8	6,018	4,803	6,528
Kansas	103	15	888	-	1,026	698	832
Kentucky	204	83	1,351	17	1,655	1,201	1,550
Michigan	4,987	1,272	21,962	545	29,186	22,234	30,252
Minnesota	2,618	1,165	11,895	937	16,593	12,127	17,011
Missouri	476	400	5,759	5	6,640	5,644	6,641
Nebraska	233	180	1,938	-	2,351	2,045	2,505
North Dakota	180	108	1,578	-	2,066	2,032	2,634
Ohio	1,149	682	13,155	437	15,423	12,968	15,105
Oklahoma	108	101	1,390	-	1,599	1,201	1,335
South Dakota	171	100	1,567	-	2,438	1,801	2,839
Tennessee	163	109	1,599	-	1,871	1,561	2,063
Wisconsin	2,130	1,257	15,821	832	19,150	15,249	19,604
Total 1973	18,136	8,002	115,685	3,935	146,157	XXX	XXX
Total 1972	18,988 2/	8,531	117,674	5,808	XXX	117,674	150,298
District III							
Alabama	84	74	1,549	-	1,657	1,267	1,325
Arkansas	50	45	893	-	988	947	1,017
Louisiana	60	78	111	10	429	218	297
Mississippi	85	53	1,416	-	1,556	1,226	1,259
New Mexico	217	168	182	7	574	162	493
Texas	706	152	3,993	195	4,866	3,818	4,485
Total 1973	1,202	577	7,964	212	10,050	XXX	XXX
Total 1972	1,045	651	7,038	108	XXX	7,038	8,874
District IV							
Colorado	106	147	771	-	1,064	650	1,519
Idaho	545	601	1,611	67	2,824	1,441	2,801
Montana	194	611	532	-	1,337	446	1,219
Utah	420	144	953	576	2,034	911	1,498
Wyoming	81	77	386	108	652	499	627
Total 1973	1,646	2,080	4,253	671	8,746	XXX	XXX
Total 1972	1,590	1,936	4,448	74	XXX	5,948	7,663
District V							
Alaska	683	146	1,354	95	2,283	1,511	2,561
Arizona	16	5	771	-	790	669	984
California	425	37	3,059	30	4,286	2,861	3,202
Hawaii	-	-	104	-	104	105	105
Nevada	105	21	685	15	826	255	969
Oregon	1,160	165	3,828	50	5,203	4,571	6,356
Washington	2,554	154	6,418	40	9,166	7,578	10,188
Total 1973	5,145	583	16,651	1,289	24,260	XXX	XXX
Total 1972	5,611	625	17,580	507	XXX	17,580	24,365
United States total, 1973	33,268	14,597	446,187	41,984	536,036	XXX	XXX
United States total, 1972	33,866 2/	14,997	453,323	43,473	XXX	453,323	545,157

1/ Revised.

2/ Revised figures for No. 1 automatic burners in District II are: Illinois, 2,066; Indiana, 1,254; Iowa, 1,212; Michigan, 5,062; Minnesota, 2,538; and Tennessee, 167.

Fig. E-2. Sales of Distillate-type Heating Oils in the United States

Table 7.--Sales of Residual-Type Heating Oils in the United States, by P.A.D. District and State: 1971 and 1972

(Thousand barrels)

P.A.D. District and State	Heating oils					
	No. 5		No. 6		Total	
	1971	1972 1/	1971	1972 1/	1971	1972 1/
District I:						
New England, total	10,801	10,757	34,217	35,099	45,018	45,856
Connecticut	68	61	5,431	4,916	5,499	4,977
Maine	794	867	2,926	3,151	3,720	4,018
Massachusetts	7,221	8,086	22,791	22,694	30,012	30,780
New Hampshire	488	510	1,413	1,613	1,901	2,123
Rhode Island	1,200	1,203	2,224	2,221	3,424	3,424
Vermont	30	30	432	504	462	534
Delaware	285	244	781	252	1,066	496
District of Columbia	459	518	4,618	5,190	5,077	5,708
Florida	20	31	2,525	2,696	2,545	2,727
Georgia	875	890	1,617	1,687	2,492	2,577
Maryland	1,636	1,742	3,642	3,777	5,278	5,519
New Jersey	2,480	2,592	11,277	11,301	13,757	13,893
New York	1,300	1,384	57,810	57,768	59,110	59,152
North Carolina	1,002	1,020	995	809	1,997	1,829
Pennsylvania	7,171	7,216	8,036	8,068	15,207	15,284
South Carolina	145	152	55	55	200	207
Virginia	380	457	1,321	1,282	1,701	1,739
West Virginia	285	488	122	71	407	559
Total	26,119	27,491	127,516	128,055	153,855	155,546
District II:						
Illinois	4,206	4,163	5,742	6,045	9,948	10,208
Indiana	568	592	3,271	3,379	3,839	3,971
Iowa	77	82	226	42	303	124
Kansas	94	23	38	36	132	59
Kentucky	-	-	211	152	211	152
Michigan	473	556	717	691	1,190	1,047
Minnesota	990	410	399	411	389	821
Missouri	788	740	508	422	1,296	1,162
Nebraska	72	99	170	106	242	205
North Dakota	116	93	187	130	303	223
Ohio	114	117	580	713	694	830
Oklahoma	50	32	55	54	105	86
South Dakota	3	4	-	-	3	4
Tennessee	20	16	182	270	202	286
Wisconsin	293	313	380	288	673	601
Total	7,264	7,040	12,666	12,739	19,930	19,779
District III:						
Alabama	524	201	449	123	973	324
Arkansas	67	18	400	254	467	272
Louisiana	4	2	11	8	15	10
Mississippi	-	-	66	100	66	100
New Mexico	7	-	60	21	67	21
Texas	63	25	1,091	647	1,154	672
Total	665	246	2,077	1,153	2,742	1,399
District IV:						
Colorado	56	54	555	480	611	534
Idaho	53	58	112	110	165	168
Montana	161	163	47	46	208	209
Utah	115	339	243	186	558	525
Wyoming	88	87	230	214	318	301
Total	673	701	1,187	1,036	1,860	1,737
District V:						
Alaska	-	-	13	20	13	20
Arizona	-	-	-	-	-	-
California	296	417	2,873	3,064	3,169	3,481
Hawaii	65	113	19	10	84	123
Nevada	66	72	15	17	81	89
Oregon	2,086	2,605	1,220	1,908	3,306	4,513
Washington	1,616	2,423	1,432	2,001	3,048	4,424
Total	4,129	5,630	5,572	7,020	9,701	12,650
United States, total	39,070	41,108	149,018	150,003	188,088	191,111

1/ Revised.

Fig. E-3. Sales of Residual-type Heating Oils in the United States

Table 8.--Sales of Distillate-Type and Residual-Type Fuel Oils for Industrial Use (Excluding Oil Company Use) in the United States, by P.A.D. District and State: 1973 and 1972

(Thousand barrels)

P.A.D. District and State	Industrial Use			
	Distillate-type oils		Residual-type oils	
	1973	1972	1973	1972 1/
District I				
New England, total	2,785	2,705	25,295	25,897
Connecticut	973	980	7,101	7,016
Maine	177	147	7,519	8,237
Massachusetts	1,090	1,059	7,901	7,249
New Hampshire	173	105	1,449	1,580
Rhode Island	142	136	1,220	1,198
Vermont	80	78	403	397
Delaware	247	219	1,442	1,371
District of Columbia	26	11	61	119
Florida	1,473	1,070	8,218	7,268
Georgia	1,584	1,522	7,114	6,449
Maryland	1,532	973	6,772	6,981
New Jersey	2,578	2,205	9,441	9,015
New York	2,614	2,456	9,481	9,212
North Carolina	2,437	2,563	8,888	9,534
Pennsylvania	3,295	2,912	11,920	10,818
South Carolina	1,186	1,259	3,248	3,480
Virginia	1,879	1,559	7,933	6,659
West Virginia	703	749	523	495
Total	22,319	20,201	100,936	99,284
District II				
Illinois	2,044	2,380	4,455	4,007
Indiana	2,218	1,724	5,310	4,184
Iowa	851	708	125	123
Kansas	183	243	499	533
Kentucky	929	775	59	50
Michigan	2,316	2,504	2,606	1,212
Minnesota	848	962	3,896	4,365
Missouri	1,280	1,131	511	505
Nebraska	434	406	42	79
North Dakota	86	100	10	10
Ohio	5,550	4,784	2,258	1,758
Oklahoma	1,268	1,199	953	701
South Dakota	134	50	53	67
Tennessee	1,661	1,281	264	233
Wisconsin	483	493	655	765
Total	20,361	18,738	21,690	20,614
District III				
Alabama	1,417	1,285	2,014	1,033
Arkansas	606	514	1,445	576
Louisiana	1,884	1,644	2,045	1,005
Mississippi	662	658	719	270
New Mexico	814	449	472	161
Texas	1,002	2,683	3,280	1,785
Total	8,385	7,233	9,975	4,832
District IV				
Colorado	404	290	742	730
Idaho	731	650	66	70
Montana	890	774	243	227
Utah	1,077	923	1,974	1,953
Wyoming	448	410	301	130
Total	3,550	3,047	3,326	3,110
District V				
Alaska	238	202	540	842
Arizona	2,522	2,197	240	69
California	5,570	5,211	6,466	6,028
Hawaii	256	267	595	551
Nevada	438	296	40	74
Oregon	1,703	1,473	2,560	2,793
Washington	1,746	1,525	3,899	4,123
Total	12,471	11,169	14,340	14,480
United States, total	67,306	60,388	150,267	142,320

1/ Revised.

Fig. E-4. Sales of Distillate-type and Residual-type Fuel Oils for Industrial Use (Excluding Oil Company Use) in the United States

Table 9 --Sales of Distillate-Type and Residual-Type Fuel Oils for Use by Oil Companies in the United States, by P.A.D. District and State: 1973 and 1972

(Thousand barrels)

P.A.D. District and State	Oil company use			
	Distillate-type oils		Residual-type oils 1/	
	1973	1972	1973	1972
District I:				
New England, total	259	155	360	265
Connecticut	48	50	176	87
Maine	10	9	16	64
Massachusetts	88	83	115	62
New Hampshire	-	1	2	2
Rhode Island	11	10	29	49
Vermont	2	2	2	1
Delaware	7	7	229	31
District of Columbia	4	3	7	7
Florida	251	269	338	223
Georgia	56	61	152	89
Maryland	361	308	292	191
New Jersey	195	297	5,759	4,295
New York	102	119	697	526
North Carolina	59	40	66	41
Pennsylvania	478	555	6,698	6,023
South Carolina	45	24	186	101
Virginia	110	60	201	139
West Virginia	34	8	62	50
Total	2,023	1,886	15,292	12,481
District II:				
Illinois	1,085	1,022	2,604	2,267
Indiana	1,011	1,023	5,812	5,549
Iowa	24	21	-	-
Kansas	218	206	992	940
Kentucky	130	129	780	620
Michigan	216	199	657	628
Minnesota	65	71	988	869
Missouri	88	25	215	410
Nebraska	19	54	55	63
North Dakota	17	12	574	518
Ohio	522	515	2,148	2,083
Oklahoma	158	54	321	219
South Dakota	20	21	15	18
Tennessee	134	83	45	-
Wisconsin	204	216	519	246
Total	4,373	4,151	20,950	19,710
District III:				
Alabama	40	24	200	151
Arkansas	231	170	442	184
Louisiana	1,678	1,153	326	159
Mississippi	194	276	685	597
New Mexico	21	10	50	13
Texas	3,706	3,212	2,452	620
Total	5,870	4,845	4,155	1,724
District IV:				
Colorado	189	184	180	120
Idaho	20	18	-	-
Montana	31	40	1,112	967
Utah	158	129	737	738
Wyoming	406	381	639	573
Total	804	752	2,668	2,198
District V:				
Alaska	141	176	2	3
Arizona	28	27	1	2
California	903	852	5,495	5,364
Hawaii	20	15	563	744
Nevada	26	28	-	-
Oregon	232	236	189	283
Washington	428	435	1,377	1,582
Total	1,780	1,769	7,627	7,978
United States, total	14,902	13,405	50,652	44,291

1/ Includes a small amount of crude oil.

Fig. E-5. Sales of Distillate-type and Residual-type Fuel Oils for Use by Oil Companies in the United States

Table 12.--Sales of Distillate-Type and Residual-Type Fuel Oils for Use by the Military in the United States, by P.A.D. District and State: 1971 and 1972

(Thousand barrels)

	Military use[1/]			
	Distillate-type oils		Residual-type oils	
	1971	1972	1971	1972
District I:				
New England, total	932	1,341	2,818	4,339
Connecticut	115	117	245	366
Maine	293	606	50	50
Massachusetts	405	525	1,301	1,793
New Hampshire	14	16	20	40
Rhode Island	101	75	1,200	2,108
Vermont	5	2	2	2
Delaware	11	12	59	104
District of Columbia	146	22	227	145
Florida	221	242	225	267
Georgia	95	207	100	155
Maryland	731	597	519	669
New Jersey	290	543	2,552	3,109
New York	1,861	1,493	1,164	1,324
North Carolina	323	324	37	50
Pennsylvania	269	341	1,719	1,985
South Carolina	262	292	65	90
Virginia	765	680	6,110	8,653
West Virginia	19	3	-	-
Total	5,413	6,097	15,595	20,890
District II:				
Illinois	374	419	68	20
Indiana	55	46	26	13
Iowa	10	9	-	-
Kansas	146	113	25	17
Kentucky	337	388	-	-
Michigan	622	653	83	5
Minnesota	151	210	-	-
Missouri	25	32	29	80
Nebraska	48	43	-	-
North Dakota	6	13	-	-
Ohio	136	107	8	8
Oklahoma	50	41	17	297
South Dakota	1	1	-	-
Tennessee	156	175	131	-
Wisconsin	104	149	-	-
Total	2,199	2,199	407	410
District III:				
Alabama	742	675	100	26
Arkansas	195	155	-	-
Louisiana	950	871	1,176	569
Mississippi	23	20	-	-
New Mexico	303	217	-	-
Texas	2,235	2,102	524	154
Total	4,498	4,090	1,800	749
District IV:				
Colorado	171	146	17	8
Idaho	2	2	-	-
Montana	29	43	16	32
Utah	95	103	5	10
Wyoming	8	9	-	-
Total	255	303	58	50
District V:				
Alaska	737	560	10	12
Arizona	40	38	-	-
California	5,605	5,969	1,134	2,126
Hawaii	140	146	-	-
Nevada	35	45	5	4
Oregon	106	131	103	108
Washington	570	409	238	273
Total	7,233	7,298	1,490	2,523
United States, total	19,598	20,187	19,350	24,622

1/ Includes imports by the military.

Fig. E-6. Sales of Distillate-type and Residual-type Fuel Oils for Use by the Military in the United States

Table 42. - Distribution of bituminous coal and lignite, in 1973, by destination and consumer use

(Thousand short tons)

Destination	Total	Electric utilities	Coke and gas plants	Retail dealers	All others 1/
New England:					
Massachusetts	106	22	-----	23	61
Connecticut	118	69	-----	-----	49
Maine, New Hampshire, Vermont, Rhode Island	1,109	1,071	-----	7	31
Middle Atlantic:					
New York	13,290	5,469	5,444	59	2,318
New Jersey	2,524	2,425	-----	21	78
Pennsylvania	64,469	34,963	23,177	657	5,672
East North Central:					
Ohio	65,557	41,745	13,410	1,056	9,346
Indiana	45,061	25,753	13,605	450	5,253
Illinois	40,628	32,465	2,968	934	4,261
Michigan	31,685	20,294	4,876	561	5,954
Wisconsin	12,634	9,322	239	458	2,615
West North Central:					
Minnesota	9,161	6,862	1,082	247	970
Iowa	6,859	5,359	-----	71	1,459
Missouri	17,385	15,451	319	191	1,424
North Dakota and South Dakota	5,816	5,381	-----	114	321
Nebraska and Kansas	3,527	3,086	-----	27	414
South Atlantic:					
Delaware and Maryland	10,596	4,789	4,850	32	925
District of Columbia	548	265	-----	24	259
Virginia	7,910	4,944	-----	450	2,516
West Virginia	32,305	22,502	5,196	243	4,364
North Carolina	19,820	17,999	-----	381	1,440
South Carolina	6,999	5,663	-----	230	1,106
Georgia and Florida	16,894	16,434	-----	72	388
East South Central:					
Kentucky	25,078	21,734	1,162	314	1,868
Tennessee	22,238	19,588	193	358	2,099
Alabama and Mississippi	27,695	18,189	7,105	90	2,311
West South Central:					
Arkansas, Louisiana, Oklahoma, and Texas	8,389	4,840	953	4	2,252
Mountain:					
Colorado	6,490	4,672	1,114	168	536
Utah	3,957	1,202	1,814	187	754
Montana and Idaho	1,395	889	-----	211	295
Wyoming	6,200	5,932	-----	22	246
New Mexico	7,343	7,325	-----	-----	18
Arizona and Nevada	4,451	4,313	-----	1	137
Pacific:					
Washington and Oregon	3,510	3,246	-----	32	232
California	2,198	-----	2,185	-----	13
Alaska	707	231	-----	13	463
Canada 2/	16,052	7,439	7,376	270	967
Mexico	305	-----	126	-----	179
Destinations not revealable	1,755	231	601	37	3/886
Destinations and/or consumer uses not available:					
Great Lakes movement:					
Canadian commercial docks	174	-----	-----	-----	-----
Vessel fuel	600	-----	-----	-----	-----
U.S. dock storage	-117	-----	-----	-----	-----
Tidewater movement:					
Overseas exports (except Canada)	4/15,570	-----	-----	-----	-----
Bunker fuel	-----	-----	-----	-----	-----
U.S. dock storage	-----	-----	-----	-----	-----
Railroad fuel:					
U.S. companies	224	-----	-----	-----	-----
Canadian companies	5	-----	-----	-----	-----
Coal used at mines and sales to employees	1,600	-----	-----	-----	-----
Net change in mine inventory	-922	-----	-----	-----	-----
Total	589,788	-----	-----	-----	-----

1/ Excludes vessel fuel and bunker fuel, the destinations of which are not available.
2/ Excludes shipments to Canadian Great Lakes commercial docks and Canadian railroad companies.
3/ Includes overseas exports from producing districts 13 and 14.
4/ Excludes overseas exports from producing districts 13 and 14.

Fig. E-7. Distribution of Bituminous Coal and Lignite

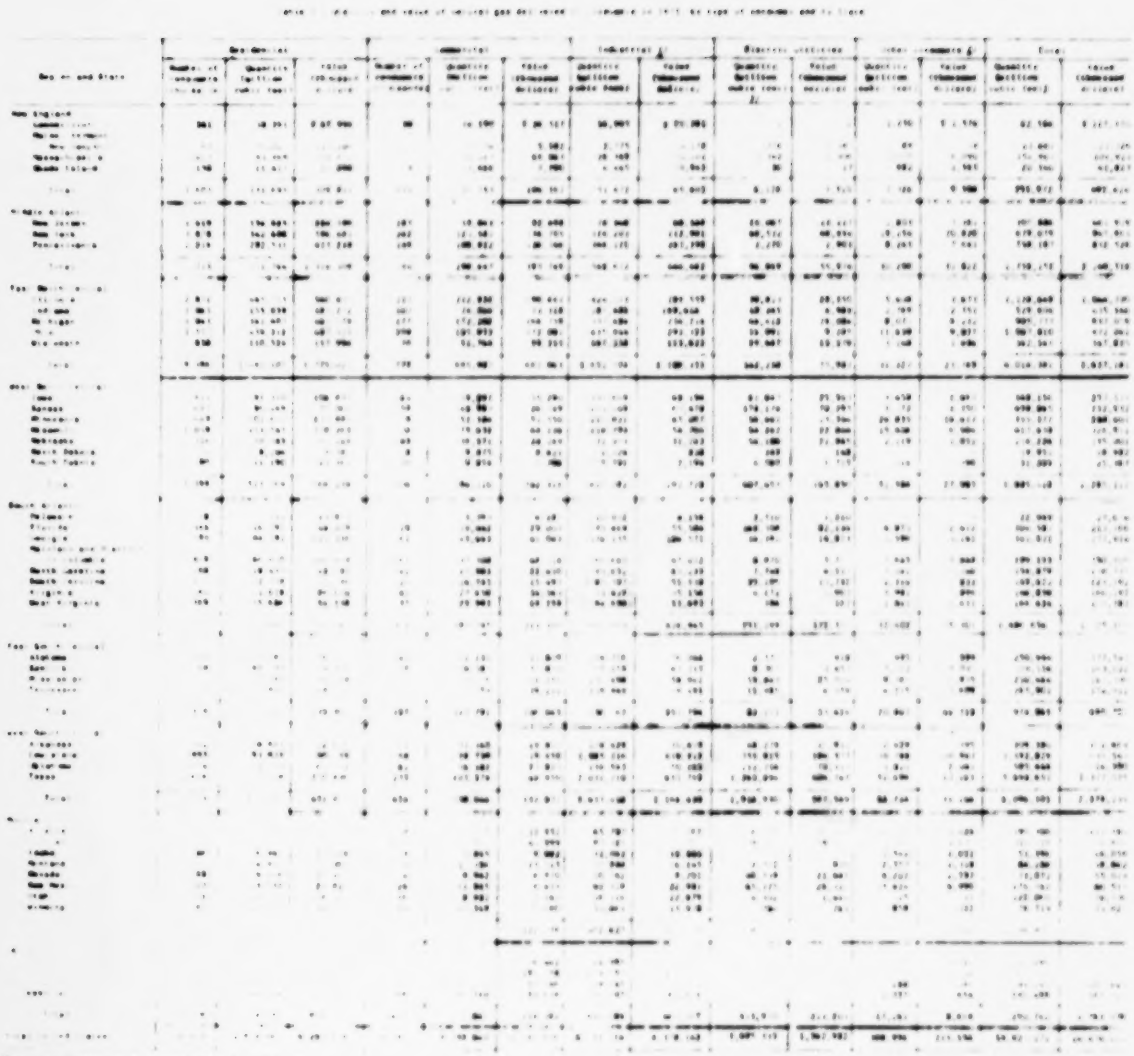

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Fig. E-8. Quantity and Value of Natural Gas Delivered to Consumers

APPENDIX F
FUGITIVE DUST CALCULATIONS

This information in this Appendix is distilled from Supplement 5 to Ref 27.

A number of significant sources of atmospheric dust consist of operations which involve the mechanical disturbance of granular material exposed to the air environment. The dust generated from these open sources is termed "fugitive" because it is not discharged to the atmosphere in a confined flow stream. Common sources of fugitive dust include: (1) unpaved roads, (2) agricultural tilling, (3) aggregate storage piles, and (4) heavy construction operations.

For the above categories of fugitive dust sources, the dust generation process is comprised of two basic physical phenomena:

1. Pulverization and abrasion of surface material by application of mechanical force through implements (wheels, blades, etc.).

2. Entrainment of dust particles by the action of turbulent air currents. Airborne dust may also be generated independently, by wind erosion of an exposed surface if the wind speed exceeds about 12 mph (19 km/hr).

The air pollution impact of a fugitive dust source depends on the quantity and drift potential of dust particles injected into the atmosphere. In addition to large dust particles that settle out near the source (often creating a localized nuisance problem), considerable amounts of fine particles are also emitted and dispersed over much greater distances from the source.

Control techniques for fugitive dust sources generally involve watering, chemical stabilization, or reduction of surface wind speed using windbreaks or source enclosure. Watering, the most common method, generally has the lowest cost, but provides only temporary dust control. Use of chemicals to treat exposed surfaces provides longer term dust suppression, but may be costly, have adverse impacts on plant and animal life, or contaminate the treated material. Windbreaks and source enclosure are often impractical due to the size of fugitive dust sources. At present, very limited data are available for estimation of the control efficiencies of these methods.

F.1 UNPAVED ROADS (DIRT AND GRAVEL)

The quantity of fugitive dust emissions from an unpaved road, per vehicle-mile of travel, may be estimated (within ± 20%) using the following empirical expression:

$$E = 0.81\ s\left(\frac{S}{30}\right)\left(\frac{365 - w}{365}\right) \qquad \text{(F-1)}$$

where E = emission factor (pounds per vehicle-mile),

s = silt content of road surface material (percent),

S = average vehicle speed (miles per hour),

w = mean annual number of days with 0.01 in. (0.254 mm) or more of rainfall (see Fig. F-1).

The equation is valid for vehicle speeds in the range 30-50 mph (48-80 km/hr).

On the average, dust emissions from unpaved roads, as given by Equation F-1, have the following particle size characteristics:

Particle Size	Weight Percent
< 30 μm	60
> 30 μm	40

The 30 μm value was determined to be the effective aerodynamic cutoff diameter for the capture of road dust by a standard high-volume filtration sampler, based on a particle density of 2-2.5 g/cm^3. On this basis road dust emissions of particles larger than 30-40 μm in diameter are not likely to be captured by high-volume samplers remote from unpaved roads. Furthermore, the potential drift distance of particles is governed by the initial injection height of the particle, the particle's terminal settling velocity, and atmospheric turbulence. Theoretical drift distances, as a function of particle diameter and mean wind speed, have been computed for unpaved road emissions. These results indicate that for a typical mean wind speed of 10 miles per hour (16 km/hr), particles larger than about 100 μm are likely to settle out within 20-30 feet (6-9 m) from the edge of the road. Dust that settles within this distance is not included in Equation F-1. Particles 30-100 μm in diameter are likely to undergo impeded settling. These particles, depending upon the extent of atmospheric turbulence, are likely to settle within a few hundred feet from

MEAN NUMBER OF DAYS WITH 0.01 INCH OR MORE OF PRECIPITATION, ANNUAL[4]

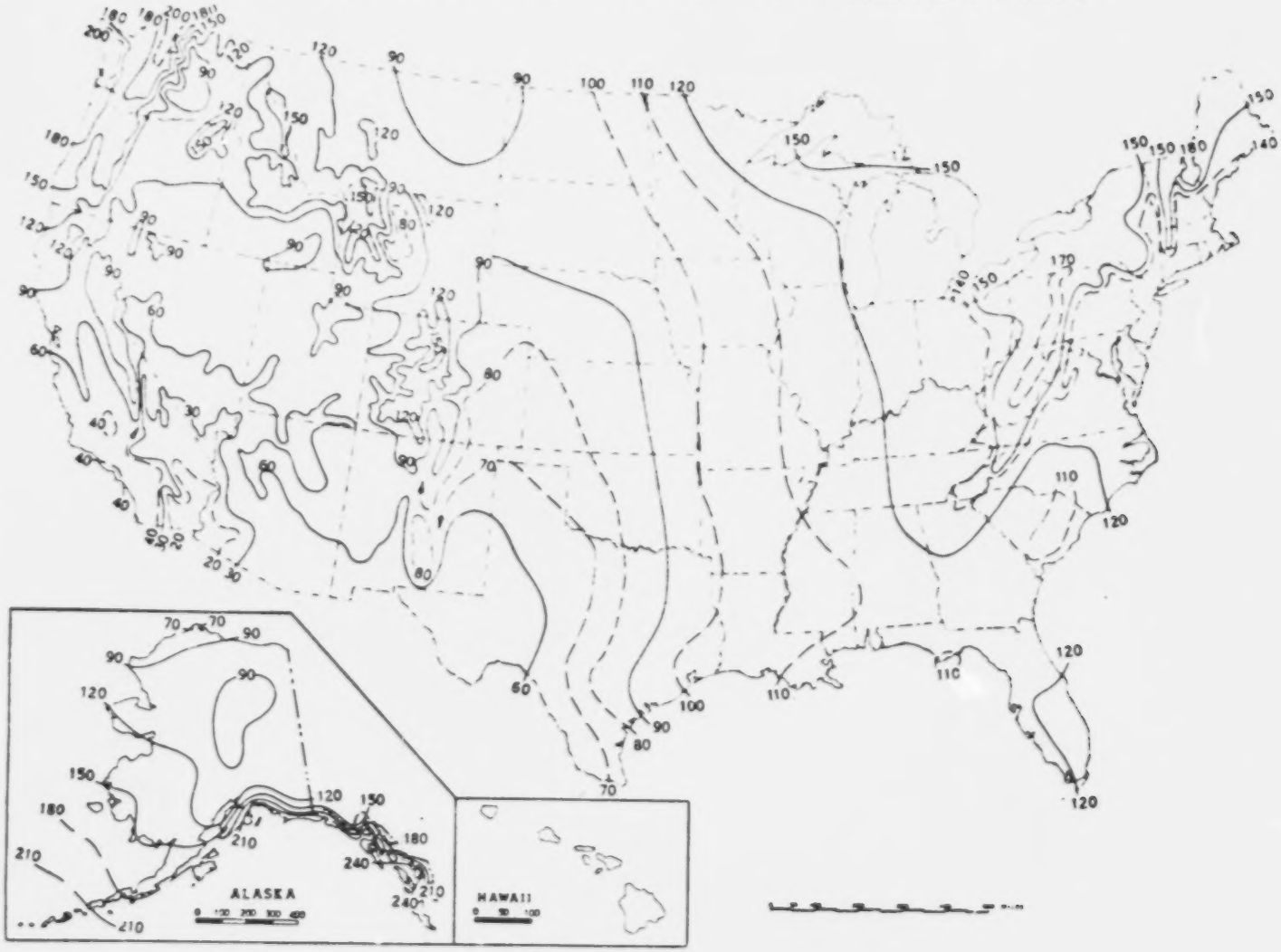

Fig. F-1. Map of Precipitation Frequency

the road. Smaller particles, particularly those less than 10-15 μm in diameter, have much slower gravitational settling velocities and are much more likely to have their settling rate retarded by atmospheric turbulence. Thus, based on the presently available data, it appears appropriate to report as emissions that may remain indefinitely suspended only those particles smaller than 30 μm [60% of the emissions predicted by Equation F-1].

Table F-1 shows approximate control efficiencies achievable for each control method.

Table F-1. Control Methods for Unpaved Roads

Control Method	Approx. Control Efficiency
Paving	85%
Surface treatment with penetration chemicals	50%
Working soil stabilization chemicals into roadbed	50%
Speed control[a]	35mph - 15% 20mph - 60% 15mph - 80%

[a]Based on the assumption that "uncontrolled" speed is typically 35 mph. Between 30-50 mph emissions are linearly proportional to vehicle speed. Below 30 mph, however, emissions appear to be proportional to the square of the vehicle speed.

F-2 AGRICULTURAL TILLING

The quantity of dust emissions from agricultural tilling, per acre of land tilled, may be estimated (within ± 20%) using the following empirical expression:

$$E = \frac{1.4\ s}{(PE/50)^2} \qquad \text{(F-2)}$$

where E = emission factor (pounds per acre),

s = silt content of surface soil (percent),

PE = Thornthwaite's precipitation-evaporation index (Fig. F-2).

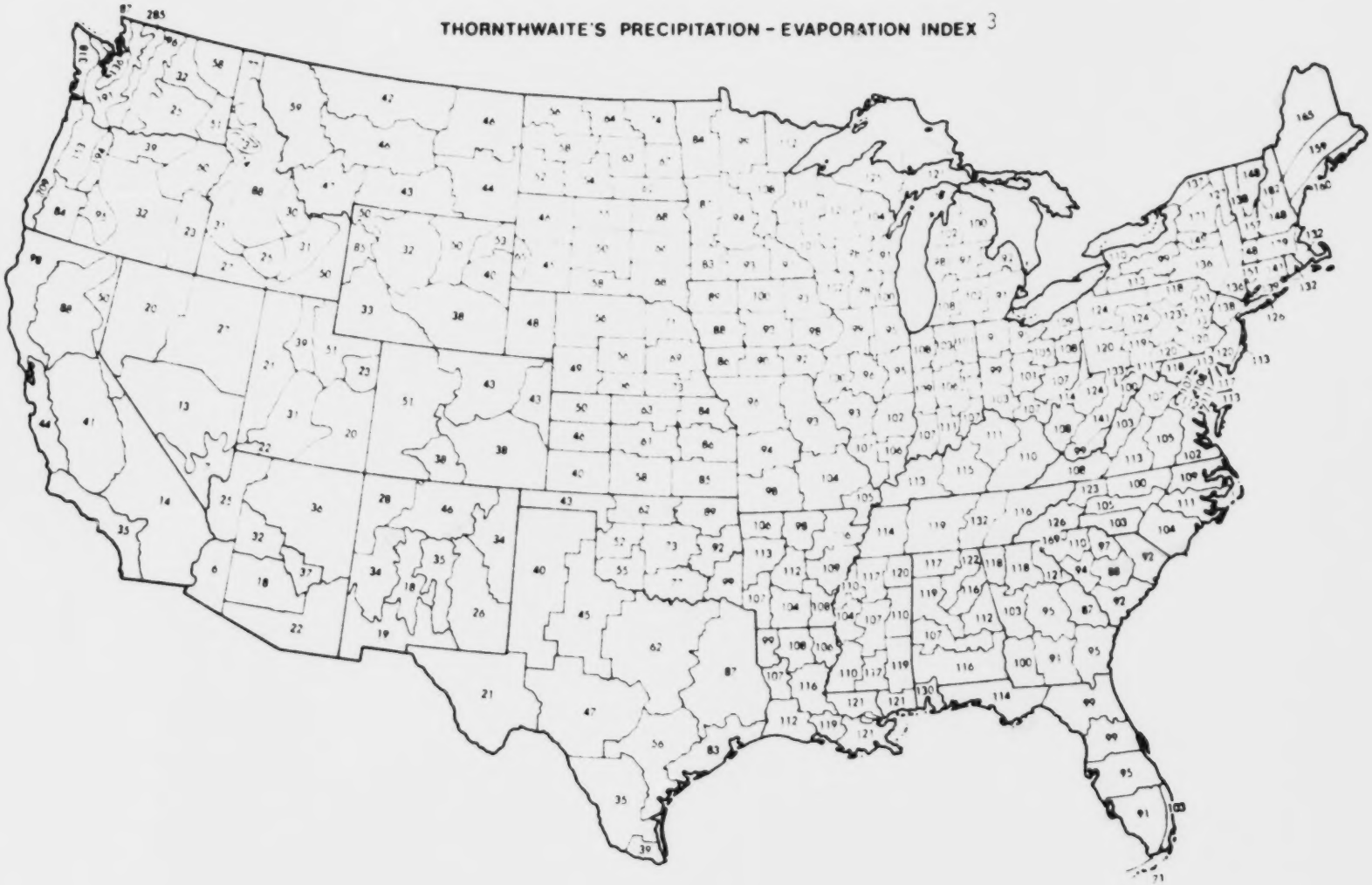

Fig. F-2. Map of PE Values for State Climatic Divisions

Equation F-2, which was derived from field measurements, excludes dust that settles out within 20-30 ft (6-9 m) of the tillage path.

On the average, the dust emissions from agricultural tilling, as given by Equation F-2, have the following particle size characteristics:

Particle Size	Weight Percent
< 30 μm	80
> 30 μm	20

The 30 μm value was determined to be the effective aerodynamic cutoff diameter for capture of tillage dust by a standard high-volume filtration sampler, based on a particle density of 2-2.5 g/cm^3. Only particles smaller than about 30 μm have the potential for long-range transport. Thus, for agricultural tilling about 80% of the emissions predicted by Equation F-2 are likely to remain suspended indefinitely.

F-3 AGGREGATE STORAGE PILES

The quantity of suspended dust emissions from aggregate storage piles, per ton of aggregate placed in storage, may be estimated using the following empirical expression:

$$E = \frac{0.33}{(PE/100)^2} \qquad \text{(F-3)}$$

where E = emission factor (pounds per ton placed in storage), and
PE = Thornthwaite's precipitation-evaporation index (see Fig. F-2).

Equation F-3 describes the emissions of particles less than 30 μm in diameter. This particle size was determined to be the effective cutoff diameter for the capture of aggregate dust by a standard high-volume filtration sampler, based on a particle density of 2-2.5 g/cm^3. Since only particles smaller than 30 μm are included, Equation F-3 expresses the total emissions likely to remain indefinitely suspended.

F-4 HEAVY CONSTRUCTION OPERATIONS

Based on field measurements of suspended dust emissions from apartment and shopping center construction projects, an approximate emission factor for construction operations is 1.2 tons/acre of construction/month of activity. This figure applies to construction operations with:

1. Medium activity level.
2. Moderate silt content ($\sim$ 30%).
3. Semiarid climate (PE $\sim$ 50; see Fig. F-2).

Test data are not sufficient to derive the specific dependence of dust emissions on correction parameters.

The above emission factor applies to particles less than about 30 μm in diameter, i.e., the effective cut-off size for the capture of construction dust by a standard high-volume filtration sampler, based on a particle density of 2-2.5 g/cm^3.

Wind erosion emissions from inactive portions of the construction site can be reduced by about 80% by application of chemical stabilizers, but this represents a fairly minor reduction in total emissions compared to emissions occurring during a period of high activity.

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APPENDIX G

MATHEMATICAL DESCRIPTION OF EMISSION PROJECTION AND SUBCOUNTY ALLOCATION PROCEDURES

G.1 INTRODUCTION

A mathematical description of the emissions projection and subcounty allocations procedures has been set up. The description specifically incorporates parameters that are affected by the basic air quality control strategies. Alteration of the mathematical values of these parameters to reflect the characteristics of a strategy will permit the creation of a projected emissions inventory consistent with the strategy and hence the modeling of the projected emissions yields the regional air quality levels that would result with the strategy in effect.

List of Symbols

Subscripts:	i	Activity type (e.g., residential by number of dwelling units per structure, industrial by SIC class, etc.)
	j	Subarea (e.g., an urban place within an AQMA)
Superscripts:	e	Existing
	f	Forecast
	m	Modifications to existing (i.e., changes in existing sources)
	n	New (i.e., growth in emissions at new locations)
	g	Growth (i.e., total change)

Subarea Emissions	E^e_{ij}, (E^f_{ij})	Existing (forecast) emissions from activity type i in subarea j
Regional Emissions	E^e_i, (E^f_i)	Existing (forecast) regional total emissions from activity type i
Activity Level	P^e_{ij}	Existing level of activity i in subarea j
Emission Factor	$(EF)^e_{ij}$, $((EF)^f_{ij})$	Existing (forecast) emission factor for activity type i in subarea j

Subarea Growth Factor	G_{ij}	Growth factor for activity type i in subarea j between the baseline and forecast years
Regional Growth Factor	G_i	Total regional growth factor for activity type i between the baseline and forecast years
Allocation Parameter	A^e_{ij}, (A^f_{ij})	Existing (forecast) parameter for allocation of total regional emissions from activity type i to subarea j
Growth Allocation Factor	F_{ij}	Subarea allocation fraction of regional growth in emissions from activity type i to subarea j.

G.2 PROJECTION OF REGIONAL EMISSIONS

Existing emissions from activity type i in subarea j are a product of the activity being carried on at level P^e_{ij} and the emission rate per unit of activity, $(EF)^e_{ij}$. In most cases, the emission factors will not vary between subareas, and a single value will apply to an activity type throughout the region. Equation (1) summarizes this relationship. The regional total of emissions from activity type i is simply the summation over the subareas in the region, as expressed by Eq. (2).

$$E^e_{ij} = P^e_{ij} \; (EF)^e_{ij} \tag{1}$$

$$E^e_i = \sum_j E^e_{ij} = \sum_j P^e_{ij} \; (EF)^e_{ij} \tag{2}$$

Where the growth factors between the baseline and forecast years and the forecast emission factors are known for each subarea, the activity level in the forecast year is given by Eq. (3), and similar to Eq. (1), the forecast of emissions assumes the general form of Eq. (4) for each subarea.

$$P^f_{ij} = G_{ij} \; P^e_{ij} \tag{3}$$

$$E^f_{ij} = P^f_{ij} \; (EF)^f_{ij} = G_{ij} \; P^e_{ij} \; (EF)^f_{ij} \tag{4}$$

Forecast emissions can be considered to be made up of emissions for the baseline year and a change (growth or reduction) in emissions:

$$E^f_{ij} = E^e_{ij} + E^g_{ij} \tag{5}$$

The expression for growth in emissions from activity i in subarea j is determined by combining Eqs. (1), (4), and (5) to yield:

$$E^g_{ij} = [G_{ij}\ (EF)^f_{ij} - (EF)^e_{ij}]\ P^e_{ij} \tag{6}$$

The forecast regional total of emissions from activity i in Eq. (7) is obtained by summation over all the subareas.

$$E^f_i = \sum_j E^f_{ij} = \sum_j G_{ij}\ P^e_{ij}\ (EF)^f_{ij} \tag{7}$$

If, instead of subarea specific growth factors, only the overall regional growth factor for activity type i is known, the forecast total of activity i for the region is $G_i \sum_j P^e_{ij}$, and in Eq. (8) the product of this value and the regional emission factor for the activity yields the forecast regional total of emissions from the activity.

$$E^f_i = (G_i \sum_j P^e_{ij})\ (EF)^f_i \tag{8}$$

G.3 SUB-COUNTY ALLOCATION OF REGIONAL EMISSIONS

In the case described by Eq. (8), subcounty allocation of these total emissions depends on the existence of some allocation parameter that describes how activity i is distributed across the region in the baseline and forecast years. If A^e_{ij} and A^f_{ij} are such parameters (e.g., for industrial activity the parameters might be existing and planned industrial land area in each subarea), change in the jth area is $A^e_{ij} - A^e_{ij}$, and the total regional change is $\sum_j (A^f_{ij} - A^e_{ij})$. The fraction of the total regional change in activity i that will occur in subarea j might then be determined by Eq. (9), for which $\sum_j F_{ij} = 1$.

$$F_{ij} = \frac{A^f_{ij} - A^e_{ij}}{\sum_j (A^f_{ij} - A^e_{ij})} \tag{9}$$

With the assumption that this same fraction of the regional growth of emissions for this activity occurs in the subarea, the change in emissions for the subarea becomes:

$$E^g_{ij} = F_{ij} \; (E^f_i - E^e_i)$$

$$= F_{ij} \; [G_i \; (EF)^f_i - (EF)^e_i] \sum_j P^e_{ij} \tag{10}$$

G.4 EXAMPLE WITH INDUSTRIAL PARTICULATE EMISSION SOURCES

In the County X illustration, emissions from industrial activity presents a special case from several considerations. The existing industrial sources are inventoried as point sources. Growth of industrial sources can be due to growth in place (modification) of existing sources or to the location of industrial activities at completely new sites. These two possibilities are described by $E^g_{ij} = E^m_{ij} + E^n_{ij}$.

Growth factors are available on a regional basis for industrial subcategories (OBERS projections). The available subregional allocation parameters (Atlanta Regional Commission calculation of possible growth in planning superdistrict industrial land use) additionally describe the spatial distribution of total industrial activity.

The three steps of (1) projecting the regional totals for growth in industrial particulate emissions, (2) allocating this growth to subareas in the region, and (3) separating the allocated emissions into modifications of existing activities and siting of completely new facilities can be handled in the following reasonable, although somewhat subjective, manner. The subscript i will be taken to indicate an industrial sub-category for which a regional growth projection is available; e.g., OBERS projections are available for nearly 25 different industrial classifications in the Atlanta AQCR. Within a specific subarea, more than one activity site (or point source) of a given industrial classification might exist. To include this possibility

an additional subscript will be added to the activity level variable to number point sources of a particular type within a subarea. Thus, $P^e_{ij\ell}$ refers to the activity of industrial classification i being carried on at the ℓth such site in subarea j. Note that $\sum_{\ell} P^e_{ij\ell}$ is the total activity of industry i in subarea j. With the assumption that the particulate emission factor for industrial classification i is the same everywhere in the region, the growth in total regional particulate emissions from industry i is:

$$E^g_i = E^f_i - E^e_i = G_i \ (EF)^f_i \sum_j \sum_{\ell} P^e_{ij\ell} - (EF)^e_i \sum_j \sum_{\ell} P^e_{ij\ell}$$

$$= [G_i \ (EF)^f_i - (EF)^e_i] \sum_j \sum_{\ell} P^e_{ij\ell} \ ,$$

and the total growth in regional particulate emissions from all industries is:

$$E^g_I = \sum_i^{\text{industry}} [G_i \ (EF)^f_i - (EF)^e_i] \sum_j \sum_{\ell} P^e_{ij\ell}.$$

Only a single industrial allocation parameter is available for each subarea, from which it is possible to determine the overall industrial subarea allocation fractions, denoted by F_{Ij}. The growth in total industrial particulate emissions allocated to each subarea will be determined by the equation:

$$E^g_{Ij} = F_{Ij} \ E^g_I = F_{Ij} \sum_i^{\text{industry}} [G_i \ (EF)^f_i - (EF)^e_i] \sum_j \sum_{\ell} P^e_{ij\ell} \qquad (11)$$

Separation of the allocated growth emissions into modified sources and new sources can be based on a comparison of the allocated emissions with those that would be expected if industrial activities in all subareas were growing at the regional growth rates. If that were the case, growth in industrial particulate emissions in subarea j would be:

$$E^g_{Ij} \ (\text{uniform}) = \sum_i^{\text{industry}} [G_i \ (EF)^f_i - (EF)^e_i] \sum_{\ell} P^e_{ij\ell} \qquad (12)$$

All allocated emissions in excess of this uniform increase will be attributed to new industrial sources, which, because of uncertainty in location, will be

taken as an area source covering the subarea. Three cases are possible in the comparison of allocated emissions and the "uniform growth" emissions for the subarea. (See Fig. G-1 on page 308.)

CASE 1. The allocated growth in total industrial emissions for the subarea exceeds the subarea growth calculated using the regional industrial growth factors. That is:

$$E^{g}_{Ij} > E^{g}_{Ij} \text{ (uniform)}$$

Thus, one could assume that:

$$E^{n}_{Ij} = E^{g}_{Ij} - E^{g}_{Ij} \text{ (uniform)} = E^{g}_{Ij} - \sum_{i}^{\text{industry}} [G_i \ (EF)^{f}_{i} - (EF)^{e}_{i}] \sum_{\ell} P^{e}_{ij\ell} \ .$$

Under this condition, modification to existing sources may be assumed to be equivalent to the regional growth rate; thus:

$$E^{m}_{ij\ell} = [G_i \ (EF)^{f}_{i} - (EF)^{e}_{i}] \ P^{e}_{ij\ell} \ .$$

$$\text{(Note that } \sum_{i}^{\text{industry}} \sum_{\ell} E^{m}_{ij\ell} = E^{g}_{Ij} \text{ (uniform).)}$$

CASE 2. The subarea change in total industrial emissions is positive, but the growth is less than the subarea growth based on regional industrial growth factors.

$$0 \leq E^{g}_{Ij} \leq E^{g}_{Ij} \text{ (uniform)}$$

Under this condition no new sources will be assumed for the subarea.

$$E^{n}_{Ij} = 0$$

The changes in emissions from the existing sources will be smaller than the changes anticipated on the basis of regional growth factors. The

amount by which allocated industrial emissions for the entire subarea are smaller than uniform growth emissions is (using Eqs. (11) and (12)):

$$E^g_{Ij}\ (\text{uniform}) - E^g_{Ij} = \sum_i^{\text{industry}} \sum_\ell [G_i\ (EF)^f_i - (EF)^e_i](P^e_{ij\ell} - F_{Ij} \sum_j P^e_{ij\ell}).$$

Consideration must be given and adjustments made to ensure that assignments of portions of this difference are made using realistic increments. It may be assumed that this difference will be distributed to existing sources in proportion to their relative importance in the existing inventory for the subarea. That is, the decrement assigned to source ℓ of type i will be:

$$(E^g_{Ij}\ (\text{uniform}) - E^g_{Ij})\ \frac{E^e_{ij\ell}}{\sum_i^{\text{industry}} \sum_\ell E^e_{ij\ell}}\ .$$

For this source, then, the change between existing and forecast emissions will be:

$$E^m_{ij\ell} = E^g_{ij\ell}\ (\text{uniform}) - (E^g_{Ij}\ (\text{uniform}) - E^g_{Ij})\ \frac{E^e_{ij\ell}}{\sum_i^{\text{industry}} \sum_\ell E^e_{ij\ell}}\ .$$

$$= [G_i\ (EF)^f_i - (EF)^e_i]\ P^e_{ij\ell} - \{\sum_i^{\text{industry}} \sum_\ell [G_i\ (EF)^f_i - (EF)^e_i]$$

$$(P^e_{ij\ell} - F_{Ij} \sum_j P^e_{ij\ell})\}\ \frac{E^e_{ij\ell}}{\sum_i^{\text{industry}} \sum_\ell E^e_{ij\ell}}\ .$$

CASE 3. The subarea growth in industrial emissions is negative, but the reduction is smaller than the existing industrial emissions for the area.

$$-\sum_i^{\text{industry}} \sum_\ell E^e_{ij\ell} < E^g_{Ij} < 0\ .$$

The equation for $E^{m}_{ij\ell}$ derived for CASE 2 can also be applied when E^{g}_{Ij} is negative. The same assumptions hold, namely, no new sources come into being and emissions changes are distributed to existing sources in proportion to current relative magnitudes.

For values of E^{g}_{Ij} near $-\sum_{i}^{industry}\sum_{\ell} E^{e}_{ij\ell}$, the modifications to some of the existing sources calculated by this method might exceed $-E^{e}_{ij\ell}$ for them. In this case, all such sources can be assumed to have ceased activity in the forecast year, and the excess reduction in emissions that had been assigned to them can be redistributed among the remaining active sources, again, on the basis of their contributions to the existing inventory. When

$$E^{g}_{Ij} = -\sum_{i}^{industry}\sum_{\ell} E^{e}_{ij\ell} ,$$

all industrial activity in subarea j will have ceased.

It is possible that the allocation fraction F_{ij} might indicate a reduction in industrial emissions that exceeds the total existing industrial emissions in a subarea j. Under these conditions, all industrial activity in the subarea will have ceased. Therefore, $E^{f}_{ij\ell} = 0$. The excess reduction in emissions initially assigned to the subarea $\left(\text{i.e., } E^{g}_{Ij} + \sum_{i}^{industry}\sum_{\ell} E^{e}_{ij\ell}\right)$. will be redistributed among the subareas that continue to have industrial activity. Subarea allocation fractions might again serve as the determinant for the redistribution among these subareas.

G.5 ANALYSIS OF CONTROL STRATEGIES

The procedure developed to describe emissions projections and sub-county allocations can be adapted to a number of emissions control strategies that might be applied in air quality management planning. As examples of the modeling of control strategies, several source controls and land use planning controls will be discussed, including:

<u>Source Controls</u>

New Source Performance Standards (NSPS)
Retrofit of NSPS to existing sources
Requirement of better than NSPS for some industries

Planning Controls

Central district heating
Emission allocations
Emission density zoning

G.6 MODELING OF SOURCE CONTROLS

G.6.1 NSPS

Description of Strategy After a designated date for each industry, industrial facilities constructed at new sites and additions to existing facilities must meet specified emissions standards based on best available control technology (BACT).

Modeling of Strategy The emission projection/allocation procedure that has been developed incorporates the assumption that an emission factor in the forecast year applies to all corresponding activity, both that existing in the baseline year and that which has come into existence between the baseline and the forecast years. NSPS, however, applies only to facilities constructed after the effective date, which will probably be the beginning of an intermediate year of the analysis interval. The effect, therefore, is somewhat less than would result if NSPS emission rates were used directly as $(EF)_i^f$ in the emission projection/allocation procedure. The method of accounting for the characteristics of NSPS contained in the supplement to Vol. 13 can be adapted to the procedures and symbols developed here. In the case of no unused capacity and no retirement and replacement of facilities during the analysis interval, the regional total particulate emissions from industrial classification i for which NSPS come into effect at the beginning of the kth year of the analysis period (period length = n years) is:

$$E_i^f = (GF_i)^{\frac{k-1}{n}} \left[1 + \frac{(EF)_i^f}{(EF)_i^e} \left((GF_i)^{\frac{n-k+1}{n}} - 1 \right) \right] (EF)_i^e \sum_j \sum_\ell P_{ij\ell}^e ,$$

where $(EF)_i^f$ is the NSPS emission rate for industrial classification i.

Example: An electric arc weld/lancing operation (SCC #3-03-009-04) at a steel works in County X will have an emission factor of 0.01 lb/ton

processed under the New Source Performance Standard effective in 1978. In 1975, 170,000 tons are processed annually, and the emission factor for this operation is 0.22 lb/ton, which is in compliance with current regulations. Between 1975 and 1980, the steel works is expected to expand activities by an overall growth factor of 1.35. For this operation, therefore,

$$P^e_{ij\ell} = 170{,}000 \text{ T/yr}$$

$$(EF)^e_i = 0.22 \text{ lb/T}$$

$$(EF)^f_i = 0.01 \text{ lb/T}$$

$$(GF)_i = 1.35$$

$$n = 5$$

$$k = 4.$$

The yearly emissions from the operation in 1980 should be:

$$E^f_{ij\ell} = (1.35)^{\frac{4-1}{5}} \left[1 + \frac{.01}{.22} \left((1.35)^{\frac{5-4+1}{5}} - 1 \right) \right] 0.22 \times 170{,}000$$

$$= 1.20 \left[1 + \frac{.01}{.22} (1.12-1) \right] 37{,}400 \text{ lb/yr}$$

$$= 1.20 \times 1.05 \times 37{,}400 \text{ lb/yr}$$

$$= 47{,}100 \text{ lb/yr} = 23.6 \text{ T/yr}.$$

If no NSPS applies to an industry during the analysis period, $(EF)^f_i = (EF)^e_i$, and this equation reduces to:

$$E^f_i = GF_i \; (EF)^e_i \sum_j \sum_\ell P^e_{ij\ell} \; .$$

The regional growth in particulate emissions from industry i is:

$$E^g_i = E^f_i - E^e_i = \left\{ (GF_i)^{\frac{k-1}{n}} \left[1 + \frac{(EF)^f_i}{(EF)^e_i} \left((GF_i)^{\frac{n-k+1}{n}} - 1 \right) \right] - 1 \right\}$$

$$(EF)^e_i \sum \sum_\ell P^e_{ij\ell} \; .$$

and the regional growth in particulate emissions from all industries is:

$$\sum_{i}^{\text{industry}} \left\{ (GF_i)^{\frac{k-1}{n}} \left[1 + \frac{(EF)_i^f}{(EF)_i^e} \left((GF_i)^{\frac{n-k+1}{n}} - 1 \right) \right] - 1 \right\} (EF)_i^e \sum_{\ell} \sum P_{ij\ell}^e \, .$$

The method of subcounty allocation of the growth in total industrial particulate emissions is unaffected by NSPS. Likewise, the separation of the allocated emissions into new sources and modifications of existing sources can proceed as outlined in the earlier discussion of the industrial example, in Appendix G, with the qualification that the allocated emissions are compared with a "uniform growth" total for the subarea that is based on the application of NSPS. That is, E_{Ij}^g is compared with:

$$\sum_{i}^{\text{industry}} \left\{ (GF_i)^{\frac{k-1}{n}} \left[1 + \frac{(EF)_i^f}{(EF)_i^e} \left((GF_i)^{\frac{n-k+1}{n}} - 1 \right) \right] - 1 \right\} (EF)_i^e \sum_{\ell} P_{ij\ell}^e$$

to determine whether new sources and modifications to existing ones or only modifications will occur.

G.6.2 Retrofit of NSPS to Existing Sources

Description of Strategy As a means of providing further source control, the determination is made to require that industrial sources existing before the effective date of NSPS also meet the lower emission rates. The requirement might be applied to only a portion of the industries that have come under NSPS regulations.

Modeling of Strategy The characteristics of this strategy are basically what was used in the development of the projection procedure, i.e., that a new emission factor will apply to all activity of a specified type in the forecast year. Allowance must be made, however, for the possibility that some industrial activities will follow NSPS only for facilities constructed after the effective date, while the retrofit strategy will apply to other

industries. A simple procedure is to separate the industrial classifications into two groups: those for which NSPS is in effect and those for which NSPS emission factors are required of all facilities. Regional particulate emissions growth for the two groups can be calculated by the appropriate methods, and the total regional growth in particulates will be:

$$\sum_{i}^{\text{NSPS industry}} \left\{ (GF_i)^{\frac{k-1}{n}} \left[1 + \frac{(EF)_i^f}{(EF)_i^e} \left((GF_i)^{\frac{n-k+1}{n}} - 1 \right) \right] - 1 \right\} (EF)_i^e \sum_j \sum_\ell P_{ij\ell}^e$$

$$+ \sum_{i'}^{\text{retrofit industry}} [GF_{i'} (EF)_{i'}^f - (EF)_{i'}^e] \sum \sum_\ell P_{i'j\ell}^e .$$

Industries to which neither NSPS nor retrofit apply, i.e., $(EF)_i^f = (EF)_i^e$, will yield the same result, $(GF_i - 1)(EF)_i^e \sum_j \sum_\ell P_{ij\ell}^e$, whether grouped with NSPS or retrofit industries.

As will be the case for all source control strategies, subcounty allocation procedures and separation of growth into new sources and modification of existing ones will be unaffected by the strategy imposed. If the separation into new sources and modifications is based on the earlier industrial example, however, the value of "uniform growth" emissions in the subarea must be the one appropriate to the strategy under examination.

G.6.3 Better than NSPS and Other Emission Rate Control Strategies

Description of Strategy If application of available control technology is inadequate to assure air quality levels at or below the ambient air quality standards, more restrictive emissions controls might be imposed on some industries to be met by the development of improved control technologies. Some future date will be chosen for the effective date of the regulations; it is assumed that the necessary technological development can be achieved in the interim.

Modeling of Strategy. Although in actual application this strategy is distinctly different from the source controls discussed previously, its modeling requires no additional mathematical prescription. The requirement is merely that a different $(EF)_i^f$ be used and that k be chosen for the effective date of the regulation. If the specification is that the emission rate be some fraction, f, of the NSPS rate, this fact can be explicitly incorporated by writing $(EF)_i^f$ as f • (NSPS emission rate).

The modeling techniques described are equally applicable to industries that do not come under NSPS. In particular, control of fugitive dust can be considered as a special case of the application of a new emission factor sometime within the analysis interval, affecting either some or all sources of a particular type. Not only various rate control strategies for industrial sources, but strategies affecting the emission rates from other activity types, e.g., transportation generated fugitive dust, can be dealt with in the same fashion as the cases covered in greater detail above.

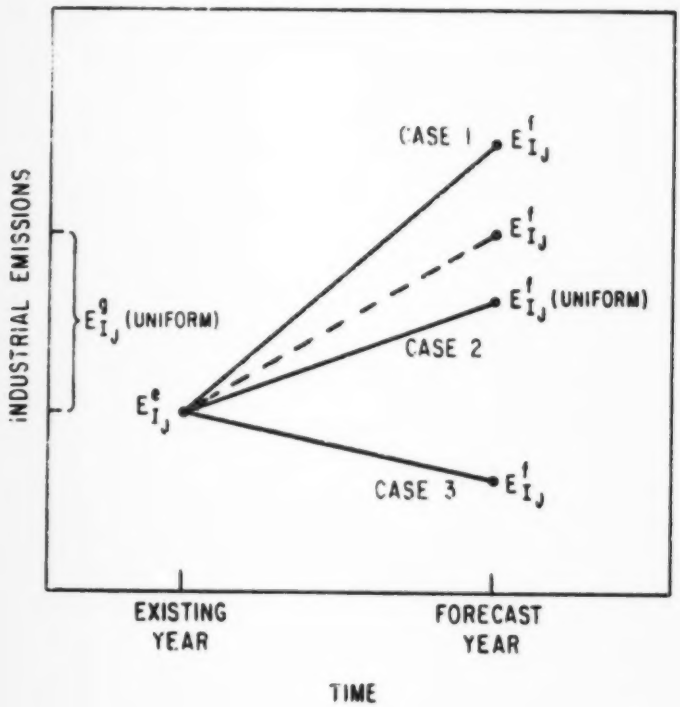


Fig. G-1. Three Cases Comparing "Uniform Growth" and Allocated Industrial Emissions

APPENDIX H
MASTER GRID MAPPING PROGRAM

All model area source datasets for the various strategies and target years are obtained by a computerized approach. Input consists of two datasets. The card output is punched according to dispersion model format requirements.

The first input dataset consists of emissions obtained from political subdivisions and census tracts. Five emission categories are involved in the computation. Emission data for two of these, residential and transportation, originate from the political subdivisions while data for the other three categories, industrial, institutional-commercial, and solid waste disposal, come from census tract information in the formulation for County X. Altogether there are eighteen emission districts with up to five emission categories each which must be mapped into the master grid. This dataset is easily constructed for each pollution control strategy and target year.

The second dataset contains the master grid characteristics. These consist of grid coordinates, area, and entry information. A master grid may have any number of entries. Each entry contains a subarea and category identification number and the fraction of that subarea that falls within the master grid. Once assembled this dataset remains unchanged.

The main algorithm carries out the repetitive process of allocating and summing emissions from a large number of emission districts and categories over a complicated grid system. The basic formulation follows:

Definition of Terms

Q_{ijk} - Emissions from subareas

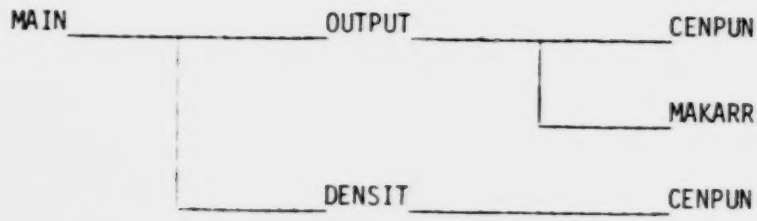
- i - Subarea
- j - Emission source category (e.g., residential, industrial etc.)
- k - Pollutant

f_{ij} - Area fraction

S_k - Emissions from master grid k.

$$S_k = \sum_j \sum_i f_{ij} Q_{ijk}$$

In words, the emissions from a subarea are allocated proportionally by the fraction of the subarea's area that lies within a master grid. This is summed coincidently over the emission categories and number of subareas that occupy each grid.



MAIN	Inputs subarea emission data, Data set #1.
OUTPUT	Inputs grid characteristics, Data set #2.
	Outputs grid characteristics.
	Calculates grid emissions for printout.
DENSIT	Inputs regional point source data.
	Adds point source emissions to appropriate grid cell.
	Prints out totals.
CENPUN	Punches area source data for use in air dispersion model.
MAKARR	Prepares grid cell data for use in DENSIT.

Fig. H-1. Grid Program Overview

SUBROUTINE MAIN

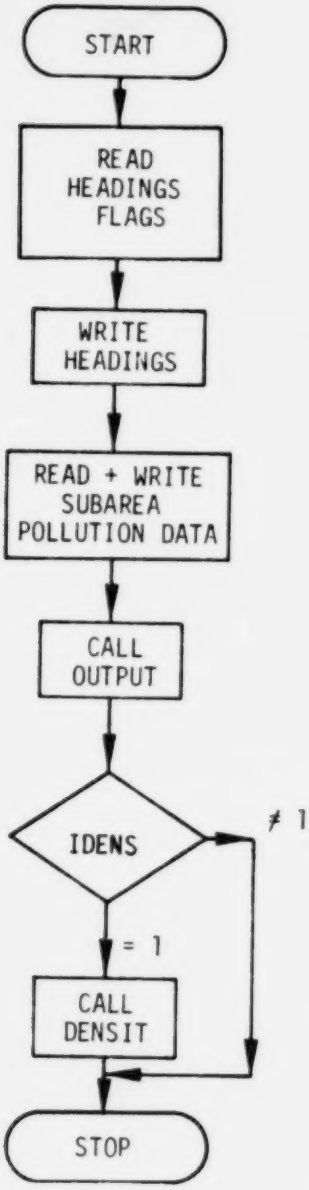


Fig. II-2. Subroutine MAIN Flowchart

SUBROUTINE OUTPUT

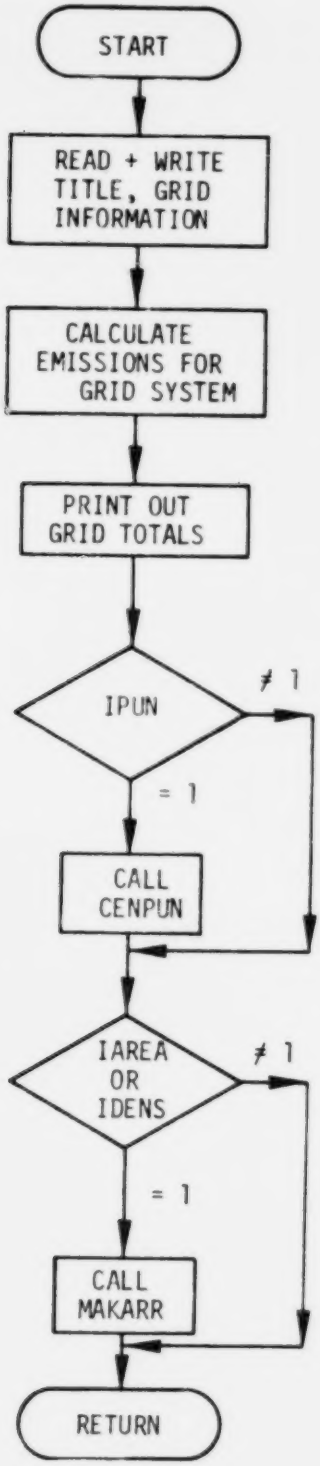
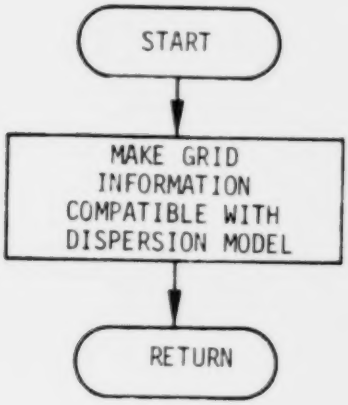


Fig. H-3. Subroutine OUTPUT Flowchart

SUBROUTINE CENPUN



SUBROUTINE MAKARR

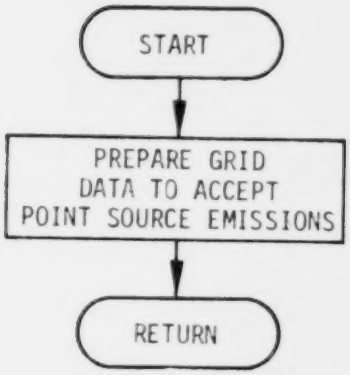


Fig. II-4. Subroutines CENPEN and MAKARR Flowchart.

SUBROUTINE DENSIT

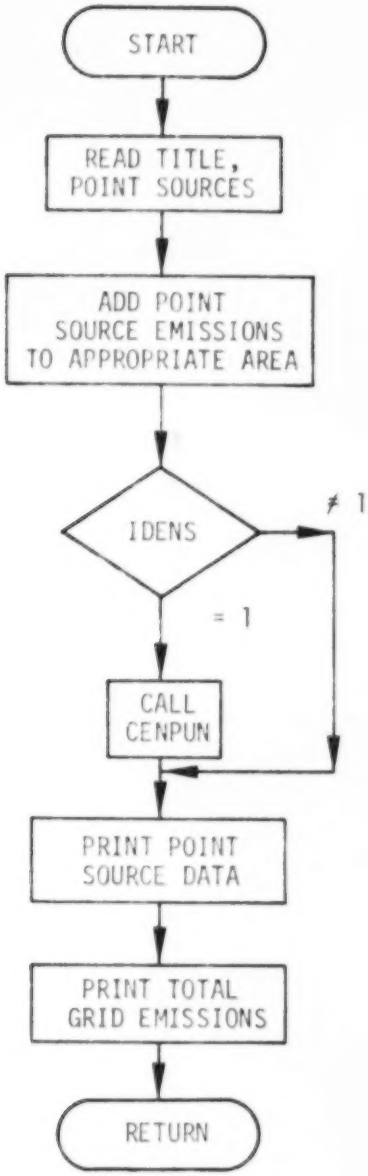
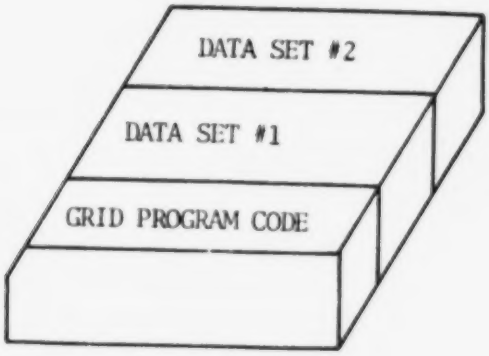


Fig. H-5. Subroutine DENSIT Flowchart



Dataset #1 Subarea Emissions Information

Card 1 Program Control Flags and Dataset Title FORMAT (4I4,16A4)

Card 2 Subarea Name FORMAT (A8)

Card 3 Emission Data FORMAT (4X,A4,6F8.2)

Columns 5-8 Pollutant name, alpha-numeric

9-16 Industrial emissions for subarea, Tons/yr,

17-24 Institutional-Commercial emissions for subarea, Tons/yr.

.

.

.

etc.

Card three is repeated for each pollutant under study.

Sets of card two and multiple card three's are repeated until all subareas are covered.

Fig. II-6. Card Input.

Dataset #2 Master Grid Information

Card 1 Dataset Title FORMAT (20A4)

Card 2 Grid Cell Characteristics FORMAT (2F10.3,F6.1,I6)

Columns 1-10, 11-20 x and y coordinates of lower left grid cell corner in UTM system.

21-26 Side length in kilometers.

27-32 Number of entries within a grid cell.

Card 3 Entry information FORMAT (5(2I4,F6.3,2I1))

Columns 1-4 Town ID #

5-8 Category ID#

9-14 Subarea fraction

.

.

.

repeated until card is full and/or all entries are completed.

Card three is repeated as needed to fully describe a grid.

Sets of cards two and three are repeated for each grid cell in the Master grid system.

Fig. H-6. Card Input (Contd.)

```
C       MAIN PROGRAM - DATA INPUT
C       EMISSION INPUT IS UNIT 5, CARDS
C       GRID INPUT IS UNIT 8, CARDS
C        AUTHOR:  JOE CAMAIONI  E.E.S. ARGONNE NATIONAL LAB
        DOUBLE PRECISION TOWN,CATEG,UNIT
        DIMENSION EMISS(20,6,5),TOWN(20),POLUT(5),CATEG(2,6),TITLE(16) ,
      *   POLTST(5)
        COMMON/ONE/UNIT,CATEG, POLTST,EMISS
        COMMON/KEY/NPOLUT,IPUN,IDENS,IAREA,ICOUNT
C       EMISS - EMISSION ARRAY COMBINING TOWNS & SUPERDISTRICTS ALONG WITH
C               EMISSION CATEGORY & POLUTANTS
C          CATEGORY  1 - INDUSTRIAL ,2 - INSTITUTIONAL/COMMERCIAL,
C                    3 - SOLID WASTE, 4 - RESIDENTIAL
C                    5 - TRANSPORTATION 6 - MISCELLANEOUS
        NTOWN=1
        READ 50,NPOLUT,IPUN,IDENS,IAREA,TITLE
        PRINT 60,TITLE
        PRINT 61,CATEG,(UNIT,I=1, 6)
      1 READ(5,51,END=2)TOWN(NTOWN),(POLUT(J),(EMISS(NTOWN,I,J),
      * I=1,6),J=1,NPOLUT)
        N=NTOWN
        PRINT 62,N,TOWN(N),(POLUT(J),(EMISS(N,I,J),I=1,6),,J=1,NPOLUT)
        DO 3 J=1,NPOLUT
        IF(POLTST(J).NE.POLUT(J))GOTO7
      3 CONTINUE
        NTOWN=NTOWN+1
        GOTO1
      2 CONTINUE
        CALL OUTPUT
        IF(IDENS.EQ.1)CALL DENSTT
        STOP
      7 PRINT 63
        STOP
     50 FORMAT(4I4,16A4)
     51 FORMAT(A8/,( 4X,A4,6F8.2) )
     60 FORMAT(1H1,///21X,16A4 )
     61 FORMAT(//3X,8HDISTRICT,3X. 8HPOLUTANT,1X,6(1X,2A6),
      *     /22X,5(4X,A8,5X)/)
     62 FORMAT(I3,1X,A8/,( 18X,A4.3X,6(F10.2,7X) ))
     63 FORMAT(//' POLUTION TYPE IN DISAGREEMENT WITH SPECIFIED ORDER FOUN
      *D IN BLOCK DATA.  PROGRAM IS STOPPED'//      )
        END
```

Fig. H-7. Program Listing

```
      SUBROUTINE OUTPUT
      DIMENSION POLUT(5),EMISS(20,6,5),NTOWN(20),NCAT(20),FRCTOT(20),
     *  TITLE(20),OTPT(6,5),CATEG(2,6),TOTAL(  5),PRCNT(6,5),A(8)
      COMMON/ONE/UNIT,CATEG,POLUT,EMISS
      COMMON/KEY/NPOLUT,IPUN,IDENS,IAREA,ICOUNT
       EQUIVALENCE (A(1),X), (A(2),Y), (A(3),S), (A(4),TOTAL(1))
      DOUBLE PRECISION UNIT,CATEG
      ICOUNT=0
      READ(8,80) TITLE
      PRINT 60,TITLE
    1 READ(8,81,END=6) X,Y,S,NENT
      READ(8,82)(NTOWN(N),NCAT(N),FRCTOT(N),N=1,NENT)
      ICOUNT=ICOUNT+1
      PRINT 601,ICOUNT
      PRINT 63,X,Y,S
      PRINT 66,(K,K=1,NENT)
      PRINT 67,(NTOWN(K),K=1,NENT)
      PRINT 68,(NCAT(K),K=1,NENT)
      PRINT 69,(FRCTOT(K),K=1,NENT)
      DO 3 K=1,5
      DO 2 I=1,6
      OTPT(I,K)=0.0
    2 PRCNT(I,K)=0.0
    3 TOTAL(K)=0.0
      DO 4 N=1,NENT
      NC=NCAT(N)
      NT=NTOWN(N)
      DO 4 K=1,NPOLUT
                              TEMP=EMISS(NT,NC,K)*FRCTOT(N)
      OTPT(NC,K )=OTPT(NC,K )+TEMP
    4 TOTAL(K)=TOTAL(K)+TEMP
```

Fig. H-7. (Cont'd)

```
      DO 5 NC=1,6
      DO 5 K=1,NPOLUT
      IF(TOTAL(K))5,5,8
    8 PRCNT(NC,K)=OTPT(NC,K)/TOTAL( K)*100.0
    5 CONTINUE
      PRINT 61,( POLUT(I),I=1,NPOLUT)
      PRINT 62,(UNIT,I=1,NPOLUT)
      DO 9 NC=1,6
      PRINT 65,(CATEG(J,NC),J=1,2),(OTPT(NC,K),PRCNT(NC,K),K=1,NPOLUT )
    9 CONTINUE
      PRINT 64,(TOTAL(K),K=1,NPOLUT)
      IF(IPUN.EQ.1) CALL CENPUN(A)
      IF(IDENS.EQ.1.OR.IAREA.EQ.1)CALL MAKARR(A)
      GOTO1
    6 CONTINUE
      RETURN
   60 FORMAT(1H1//,21X,20A4)
   61 FORMAT(   //28X,'SOURCE',7X,5(6X,A4,6X))
  601 FORMAT(//6X,'GRID NUMBER',I4/)
   62 FORMAT(27X,'CATEGORY',7X,2(A8,4X,'%',3X)/ )
   63 FORMAT(/6X,'GRID COORDINATES, X(KM) ',F10.3/,
     *    5X, '(LOW LEFT CORNER)  Y(KM) ',F10.3/,
     *   6X,'SIDE LENGTH OF SQUARE(KM)',F9.1/ )
   64 FORMAT(/27X,'TOTAL',8X,2(F8.2,8X )////)
   65 FORMAT(24X,2A8,2(F8.2,F8.0))
   66 FORMAT(6X,'ENTRY NUMBER',12X,15I7)
   67 FORMAT(6X,'TOWN I.D.#',14X,15I7)
   68 FORMAT(6X,'CATEGORY I.D.#',10X,15I7)
   69 FORMAT(6X,'FRACTIONAL MULTIPLIER',3X,15F7.3)
   80 FORMAT(20A4)
   81 FORMAT(2F10.3,F6.1,I6)
   82 FORMAT(5(2I4,F6.3,2X))
      END
```

Fig. H-7. (Cont'd)

```
      SUBROUTINE DENSIT
      DIMENSION  TITLE(15),B(8)
      COMMON/THREE/ A(10,200), SORCE(6,100)
      COMMON/KEY/ NP,IPN,ID,IA,IC
      NAMELIST/INPUT/  SORCE
      NN=NP+3
      NSORCE=66
      READ (9,90) NSORCE,TITLE
      PRINT 60, TITLE
      READ(9,INPUT)
      PRINT 61
      DO 1 I=1,NSORCE
      SORCE(6,I)=-1.0
      DO 2 J=1,IC
      IF(SORCE(1,I).LT.A(1,J).OR.SORCE(1,I).GT.A(9,J))GO TO 2
      IF(SORCE(2,I).LT.A(2,J).OR.SORCE(2,I).GT.A(10,J))GO TO 2
      DO 3 K=4,NN
      A(K,J)= A(K,J) + SORCE(K,I)*365.
    3 CONTINUE
      SORCE(6,I)=J
      GOTO1
    2 CONTINUE
    1 CONTINUE
      PRINT 62, SORCE
      PRINT 63
      PRINT 64
      DO 4 L=1,IC
      IF(IA.NE.1) GOTO6
      DO 5 M=1,NN
      B(M)=A(M,L)
    5 CONTINUE
      CALL CENPUN(B)
    6 CONTINUE
      A(9,L)=A(5,L)/A(3,L)**2.
      PRINT 62, (A(I,L),I=1,NN) ,A(9,L)
    4 CONTINUE
      RETURN
   60 FORMAT(1H1//,10X,15A4//)
   61 FORMAT(22X,'UTMX',12X,'UTMY',8X,'AREA(KM)',7X,'SO2 TN/DY',
     *     6X,'PART TN/DY',12X,'HSE'/)
   62 FORMAT(14X,6F16.3)
   63 FORMAT(//1H1,10X,'EMISSION DENSITY INFORMATION OF AREA SOURCES IN
     *MASTER GRID'//)
   64 FORMAT(22X,'UTMX',12X,'UTMY',4X,'SIDE LEN. KM',7X,'SO2 TN/YR',
     *    6X,'PART TN/YR'/ )
   90 FORMAT(I4,15A4)
      END
```

Fig. H-7. (Cont'd)

```
      SUBROUTINE MAKARR(A)
      DIMENSION A(8)
      COMMON/KEY/NP,IP,ID,IA,IC
      COMMON/THREE/ ARRAY(10,200)
      M=NP+3
      DO 1 J=1,M
      ARRAY(J,IC)=A(J)
    1 CONTINUE
      ARRAY(9,IC)=ARRAY(1,IC)+ARRAY(3,IC)
      ARRAY(10,IC)=ARRAY(2,IC)+ARRAY(3,IC)
      RETURN
      END



      SUBROUTINE CENPUN(A)
      DIMENSION A(6)
      COMMON/KEY/NPOLUT,IPUN,IDENS,IAREA,ICOUNT
      HEIGHT=0.0
C     POLUTANT ORDER FOR AQDM 1-SO2,2-PART
C     CENTERS COORDINATE ORIGINALLY LOCATED AT SOUTH-WEST CORNER OF GRID.
C     PUNCHES AQDM INPUT.
      X=A(1)+A(3)/2.
      Y=A(2)+A(3)/2.
      AREA=A(3)*A(3)
C     EMISSION RATE CHANGED FROM TONS/YR TO TONS/DAY
      NN=3+NPOLUT
      DO 10 K=4,NN
      A(K)=A(K)/365.
   10 CONTINUE
       PUNCH 70, X, Y, AREA, A(4),A(5), HEIGHT
      RETURN
   70 FORMAT(10X,6(F9.3,','))
      END


      BLOCK DATA
      DOUBLE PRECISION UNIT,CATEG
      COMMON/ONE/UNIT,CATEG(2,6),POLUT(5),EMISS(20,6,5)
      COMMON/THREE/ ARRAY(10,200) ,SORCE(6,100)
      DATA SORCE / 600*0.0 /
      DATA EMISS/600*0.0/
      DATA CATEG/8H    INDUS,8HTRIAL    ,8H INSTIT-,8HCOMMERCE,8H  SOLID ,
     * 8HWASTE    ,8H    RESID,8HENTIAL   ,8H  TRANSP,8HORTATION,
     * 8HMISCELLA,8HNEOUS    /
      DATA UNIT/'TONS/YR '/
      DATA POLUT/'SO2 ','PART',' CO',' HC ',' NOX'/
      DATA ARRAY/ 2000*0.0/
      END
```

Fig. H-7. (Cont'd)

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SOLUTION 3-1

Use of Larsen's graphical method to determine the existence of short-term particulate problems.

1. From the SAROAD printout of Fig. 3-1, the geometric mean is 57.73 $\mu g/m^3$. Plot this as the 50% point. The geometric standard deviation is 1.72.

2. The C_{16} point is calculated using Eq. (3-1) as: C_{16} = (57.73)(1.72) = 99.30. Plot this at the 16% point.

3. The C_{84} point is calculated using Eq. (3-2) as: C_{84} = (57.73)/(1.72) = 33.56. Plot this at the 84% point. These 3 points can then be used to draw the Larsen line.

4. From Eq. (3-5) the second highest value can be expected at the 0.44% line. Read from the Larsen line, this value is 235 $\mu g/m^3$. The highest value is, from Eq. (3-4), at the 0.16% line and is read as 280 $\mu g/m^3$. If these two values had been found in an actual sampling program, they would show a violation of the secondary short-term standard (the SMP concentration exceeds 150 $\mu g/m^3$) but not the primary short-term standard, since only the highest concentration, but not the SMP concentration, exceeds 260 $\mu g/m^3$. However, these are only estimates and cannot be used to determine compliance with NAAQS. This analysis does show that the secondary short-term standard is almost certainly being violated at this site particularly since, with only 55 out of a possible 365 samples, a maximum of 181 $\mu g/m^3$ was observed. The analysis strongly suggests that the primary short-term standard is close to being violated. Since there is no reason to believe that the monitor involved measures the highest 24-hour concentrations in the vicinity, this analysis indicates that the modeling results from this area should be scrutinized carefully for short-term primary standard violations.

5. When the measured data is plotted, the fit between the Larsen line and the plotted points is excellent. The data appear to be lognormal to a satisfactory degree and estimates of extreme values are made with confidence. Generally, the agreement between the measured frequency distribution is not as close as in this illustration. If a numerical estimate of the degree of confidence in the fit is desired, then the statistical χ^2 test would have to be used.

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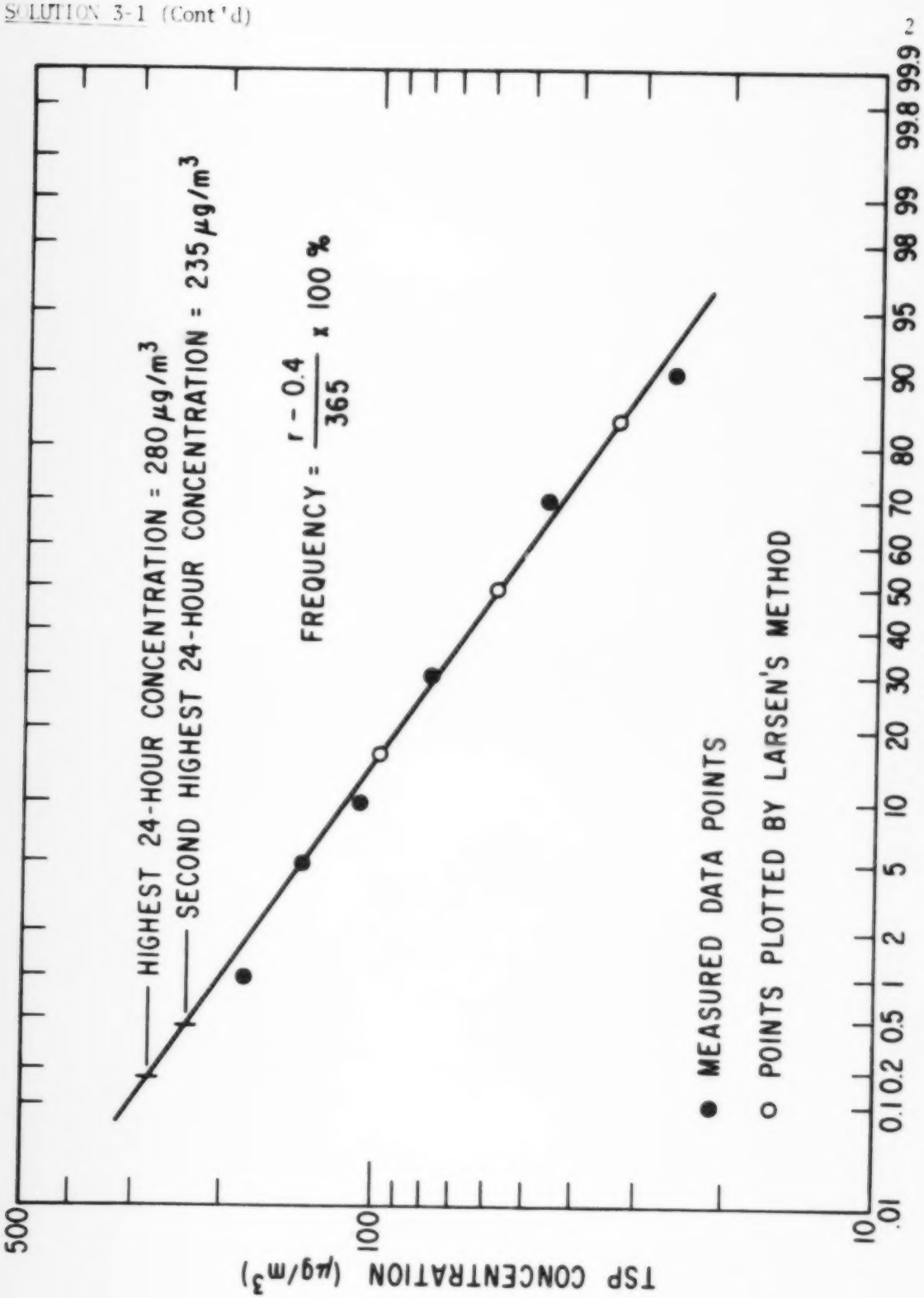


SOLUTION 3-1. Larsen's Method Applied to County X

SOLUTION 3-2

Updating the emission inventory for fuel combustion sources using a Level 2 analysis.

Following the procedures outlined in Ref. 7, pp 61-67:

1. OIL

a. Start with Mineral Industry Survey Data

Fill in Table 2.4 as indicated with data from Appendix E.

Convert from 1000 bbl to 1000 gal by factor of 42 gal/bbl.

b. Estimate employment distribution between manufacturing and commercial institutional

From Fig. C-1:

1973 manufacturing employment	=	482,360
1973 commercial/institutional employment (including wholesale trade, retail trade, finance, services, and unclassified)	=	729,121
Total		1,211,481
Thus, manufacturing employment	=	39.8%
commercial/institutional employment	=	60.2%

Enter on Table 2.4 in Lines 2 and 3.

c. Estimate residential oil use

From Fig. C-3:

1973 Georgia population = 4,786,000

From Fig. C-4:

The people per occupied housing unit = 3.3

Thus, the 1973 number of housing units is:

$$\frac{4,786,000}{3.3} = 1,450,303$$

SOLUTION 3-2 (Contd.) 2

From Fig. C-5:

The number of occupied housing units in 1970 = 1,369,225

67,956 use oil for heating

$$\frac{67,956}{1,369,225} = 5.0\%$$

808,597 use utility gas for heating
250,328 use bottled gas for heating
1,058,925

$$\frac{1,058,925}{1,369,225} = 77.3\%$$

1,922 use oil for water heating

$$\frac{1,922}{1,369,225} = 0.1\%$$

Thus, the number of housing units using oil for heating in 1973 is:

(.050)(1,450,303) = 72,515

The number using oil for water heating is:

(.001)(1,450,303) = 1,450

From Ref. 39, the number of degree days in the Atlanta area is 2983.

Thus, the annual residential distillate oil use is:

$$72,515 \begin{bmatrix}\text{housing units}\\ \text{using oil}\\ \text{for heating}\end{bmatrix} \times 0.18 \left[\frac{\text{gal oil}}{\text{degree day-housing unit}}\right]$$

$$\times 2983 \text{ [degree days]}$$

$$+ 1,450 \begin{bmatrix}\text{housing units}\\ \text{using oil for}\\ \text{water heating}\end{bmatrix} \times 250 \text{ [gallons oil]}$$

$$= 39,298 \text{ [1000 gals]}$$

Enter on Table 2.4, line 9.

d. Compute commercial/institutional and industrial oil use

Commercial/institutional oil fraction (line 4)

= (.602)(130,410 - 39,298) = 54,849 1000 gals distillate

= (.602)(104,664 - 0) = 63,007 1000 gals residual

Industrial oil fraction (line 5)

= 130,410 - 39,298 - 54,849 = 36,263 1000 gals distillate

= 104,664 - 63,007 = 41,657 1000 gals residual

2. COAL

a. Start with Mineral Industry Surveys

From Fig. E-7, 1973 bituminous and lignite coal consumption for Florida and Georgia is:

72,000 tons - residential and commercial/institutional (category "retail dealers")

388,000 tons - industrial (category "all others")

b. Disaggregate to Georgia and Florida by heating degree-days

From Ref. 39:

Georgia average degree-days = 2,000
Florida average degree-days = 750
2,750

Thus, Georgia is $\frac{2,000}{2,750}$ or 72.7%.

1973 Georgia industrial coal is (.727)(388,000) = 282,076

1973 residential and commercial/institutional coal is (.727)(72,000) = 52,344

c. Estimate residential coal use

From Fig. C-5:

1970 number of housing units using coal for heat = 24,754

Assume no growth in the use of residential coal.

SOLUTION 3-2 (Contd.) 4

$$\text{1973 residential coal use} = 24{,}754 \begin{bmatrix}\text{housing}\\ \text{units using}\\ \text{coal}\end{bmatrix} \times .0012 \begin{bmatrix}\dfrac{\text{tons coal}}{\text{degree day-}}\\ \text{housing unit}\end{bmatrix}$$

$$\times \text{ 2000 degree-days}$$

$$= \text{59,410 tons}$$

This is significantly larger than the total residential and commercial/institutional coal use. Therefore, assume the 1973 residential and commercial/institutional coal use to be distributed in the same proportion as the NEDS fuel report (Fig. B-3).

NEDS residential coal use	=	57,600 tons
	=	94.7%
NEDS commercial/institutional coal use	=	3,208 tons
	=	5.3%

Thus,

1973 residential coal use = (.947)(52,344) = 49,570
1973 commercial/institutional coal use = (.053)(52,344) = 2,774 tons

3. NATURAL GAS

a. Start with Mineral Industry Surveys

From Fig. E-8:

1973 residential gas consumption	= 86,191	$10^6 ft^3$
1973 commercial/institutional gas consumption (includes categories "commercial" and "other")	= 47,253	$10^6 ft^3$
1973 industrial gas consumption	= 174,135	$10^6 ft^3$

4. DISAGGREGATE TO POINT AND AREA SOURCES

a. From NEDS fuel report (Fig. B-3)

	Residual Oil		Distillate Oil	
	Quantity (1000 gal)	%	Quantity (1000 gal)	%
Industrial				
Point Sources	311,592	99.6	8,074	9.7
Area Sources	1,260	0.4	74,970	90.3

SOLUTION 3-2 (Contd.)

	Residual Oil		Distillate Oil	
	Quantity (1000 gal)	%	Quantity (1000 gal)	%
Commercial/Institutional				
Point Sources	620	0.2	8,102	3.2
Area Sources	315,000	99.8	245,820	96.8

	Coal		Gas	
	Qty. (T)	%	Qty. (T)	%
Industrial				
Point Sources	186,062	57.7	40,334	32.2
Area Sources	136,320	42.3	84,910	67.8
Commercial/Institutional				
Point Sources	3,208	100.0	3,052	5.8
Area Sources	0	0	49,230	94.2

Prorate the 1973 figures accordingly:

1973 industrial point source residual oil = (.996)(346,829)
= 345,442 10^3 gal

1973 industrial area source residual oil = (.004)(346,829)
= 1,387 10^3 gal

1973 industrial point source distillate oil = (.097)(105,143)
= 10,199 10^3 gal

1973 industrial area source distillate oil = (.903)(105,143)
= 94,944 10^3 gal

1973 industrial point source coal = (.577)(282,076)
= 162,758 tons

1973 industrial area source coal = (.423)(282,076)
= 119,318 tons

1973 industrial point source gas = (.322)(174,135)
= 56,072 10^6 ft^3

1973 industrial area source gas = (.678)(174,135)
= 118,063 10^3 ft

1973 commercial/institutional point source residual oil = (.002)(67,207)
= 134 10^3 gal

SOLUTION 3-2 (Contd.)

1973 commercial/institutional area source residual oil	= (.998)(67,207) = 67,073 10^3 gal
1973 commercial/institutional point source distillate oil	= (.032)(58,839) 1,883 10^3 gal
1973 commercial/institutional area source distillate oil	= (.968)(58,839) = 56,956 10^3 gal
1973 commercial/institutional point source coal	= (1.000)(2,774) = 2,774 tons
1973 commercial/institutional area source coal	= (0)(0) = 0 tons
1973 commercial/institutional point source gas	= (.058)(47,253) = 2,741 10^6 ft^3
1973 commercial/institutional area source gas	= (.942)(47,253) = 44,512 10^6 ft^3

Enter results on Table 2.5.

5. APPORTION STATE TOTALS TO COUNTY

a. Residential

From Figs. C-5 and C-7:

No. housing units using:	State	County X	County % of State
Coal	24,754	1,413	5.7
Oil	67,956	4,199	6.2
Gas (utility & bottled)	1,058,925	172,247	16.3

Thus, county portion of residential fuel use is:

Coal:	(.057)(49,570)	=	2,825 tons
Distillate oil:	(.062)(39,298)	=	2,436 1000 gal
Gas:	(.163)(86,191)	=	14,049 10^6 ft^3

Enter on Table 2.1.

b. Commercial/Institutional

From Figs. C-4 and C-6:

County X population	=	607,592
State population	=	4,589,575

Thus, County X has 13.2% of state population.

The county portion of commercial/institutional fuel use is:

residual oil	(point):	(.132)(134)	=	18	1000 gal
residual oil	(area) :	(.132)(67,073)	=	8,854	
distillate oil	(point):	(.132)(1,883)	=	249	
distillate oil	(area) :	(.132)(56,956	=	7,518	
gas	(point):	(.132)(2,741)	=	362	$10^6 ft^3$
gas	(area) :	(.132)(44,512)	=	5,876	

Enter on Table 2.1.

c. Industrial

From Figs. C-1 and C-2, and Ref. 7, p 65:

Category	State Employment	County Employment	Fuel Intensity Ratio
Food and kindred products	47,041	7,688	.27
Textile mill products	118,217	2,354	.13
Apparel and other fabrics	71,558	6,743	.03
Lumber products & furniture	36,182	4,466	.27
Paper and allied products	25,899	5,159	.69
Printing and publishing	14,741	7,137	.04
Chemicals & allied products	16,310	3,255	.88
Petroleum refining	10,710	1,213	2.83
Primary metals	10,917	2,098	.87
Fabricated metals	17,866	2,857	.13
Machinery, except electrical	14,538	3,034	.08
Electrical machinery	11,547	1,122	.06
Transportation equipment	39,457	9,785	.09
Other	31,112	4,392	.06
$\sum e_i f_i$ =	122,201	17,583	

$$\text{County fraction} = \frac{17,583}{122,201} = .144$$

Thus, the county portion of industrial fuel use is:

coal	(point)	(.144)(162,758)	=	23,437	tons
coal	(area)	(.144)(119,318)	=	17,182	
residual oil	(point)	(.144)(345,442)	=	49,744	1000 gal
residual oil	(area)	(.144)(1,387)	=	200	
distillate oil	(point)	(.144)(10,199)	=	1,469	
distillate oil	(area)	(.144)(94,944)	=	13,672	
gas	(point)	(.144)(56,072)	=	8,074	$10^6 ft^3$
gas	(area)	(.144)(118,063)	=	17,001	

Enter on Table 2.1

6. SULFUR AND ASH CONTENT

Lacking other data, fill in Table 2.3 using current NEDS data.

7. EMISSION FACTORS

From Ref. 27, the particulate emission factors are:

bituminous coal (residential, commercial/institutional area, industrial area):	2A = 2(7.4) = 14.8 lb/ton coal
(commercial/institutional point, industrial point):	13A = 13(7.4) = 96.2 lb/ton coal
residual oil (commercial/ institutional and industrial):	23 lb/1000 gal
distillate oil (residential)	10 lb/1000 gal
(commercial/institutional and industrial):	15 lb/1000 gal
gas (residential and commercial/ institutional)	19 lb/10^6 ft^3
(industrial):	18 lb/10^6 ft^3

For point sources, prorate each source's fuel use from the current NEDS file to the updated fuel consumption and use the indicated control efficiencies. For area sources, the emissions are calculated:

industrial area

coal	:	(14.8)(17,182)	=	254,294	lb particulates/yr
residual oil	:	(23)(200)	=	4,600	
distillate oil	:	(15)(13,672)	=	205,080	
gas	:	(18)(17,001)	=	306,018	

commercial/institutional area

residual oil	:	(23)(8,854)	=	203,642
distillate oil	:	(15)(7,518)	=	112,770
gas	:	(19)(5,876)	=	111,644

residential area

coal	:	(14.8)(2,825)	=	41,810
distillate oil	:	(10)(2,436)	=	24,360
gas	:	(19)(14,049)	=	266,931
		Total		1,531,149 lb/yr or
				766 ton/yr of particulates

Table 2.4
Apportionment of State Heating Oil Sales Totals to Customer Categories

LINE	SALES COMPONENT	FUEL USE, 1000 GAL RESIDUAL	FUEL USE, 1000 GAL DISTILLATE	
1	TOTAL HEATING OIL SALES	104,664	130,410	Fig. E-3, Column "Total, 1973" Fig. E-1, Column "Heating, 1973" and Fig. E-2, Column "Total, 1973"
2	COMM INST EMPLOYMENT FACTOR	.602	.602	Calculation 1b
3	INDUSTRIAL EMPLOYMENT FACTOR	.398	.398	
4	COMM INST OIL FRACTION	63,007	54,849	Calculation 1d
5	INDUSTRIAL OIL FRACTION	41,657	36 263	
6	SALES TO MILITARY	4,200	3,990	Fig. E-6
7	SALES TO INDUSTRY	298,788	66,528	Fig. E-4
8	OIL COMPANY USE	6,384	2,352	Fig. E-5
9	RESIDENTIAL USE	0	39,298	Calculation 1c
10	TOTAL COMM INST USE	67,207	58,839	Sum lines 4 and 6
11	TOTAL INDUSTRIAL USE	346,829	105 143	Sum lines 5,7,8

CALCULATION LEVEL 2

Table 2.5
Baseline State Fuel Use
(External Combustion Unless Noted Otherwise)

SOURCE		MAJOR FUELS: COAL: ANTHRACITE	MAJOR FUELS: COAL: BITUMINOUS	MAJOR FUELS: COAL: LIGNITE	MAJOR FUELS: RESIDUAL	MAJOR FUELS: DISTILLATE	MAJOR FUELS: DISTILLATE INTERNAL*	MAJOR FUELS: NATURAL GAS	MAJOR FUELS: NATURAL GAS INTERNAL*	MINOR FUELS: PROCESS GAS	MINOR FUELS: LPG	MINOR FUELS: COKE	MINOR FUELS: WOOD	MINOR FUELS: RAGASSE	MINOR FUELS: DIESEL INTERNAL*	MINOR FUELS: GASOLINE INTERNAL*	MINOR FUELS: ENGINE TESTS INTERNAL*	MINOR FUELS: OTHER	MINOR FUELS: OTHER INTERNAL*	ELECTRICITY: USED AS FUEL SUBSTITUTE
INDUSTRIAL	POINT	0	162,758	0	345,442	10,199	0	56,072	0											
	AREA	0	119,318	0	1387	94,944	0	118,063	0											
COMMERCIAL INSTITUTIONAL	POINT	0	2774	0	1341	883	0	2741	0											
	AREA	0	0	0	67,073	56,956	0	44,512	0											
RESIDENTIAL	AREA	0	49,570	0	0	39,298	0	86,191	0											
UNITS		TONS			1000 GALLONS			10^6 CU FT			1000 GAL	TONS			1000 GALLONS					KWH

CALCULATION LEVEL 2
DATA SOURCES Mineral Industry Surveys, Census, NEDS

*ALL INTERNAL COMBUSTION REFERS TO STATIONARY SOURCES ONLY

Table 2.1
Baseline County Fuel Use
(External Combustion Unless Noted Otherwise)

SOURCE		MAJOR FUELS: COAL: ANTHRACITE	COAL: BITUMINOUS	COAL: LIGNITE	OIL: RESIDUAL	OIL: DISTILLATE	OIL: DISTILLATE INTERNAL	NATURAL GAS	NATURAL GAS INTERNAL	MINOR FUELS: PROCESSORS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ELECTRICITY: USED AS FUEL SUBSTITUTE
INDUSTRIAL	POINT	0	23,437	0	49,744	1469	0	8074	0											
	AREA	0	17,182	0	200	13,672	0	17,001	0											
COMMERCIAL INSTITUTIONAL	POINT	0	0	0	18	249	0	362	0											
	AREA	0	0	0	8854	7518	0	5876	0											
RESIDENTIAL	AREA	0	2825	0	0	2436	0	14,049	0											
UNITS		TONS			1000 GALLONS			[illegible]			1000 GAL	TONS			1000 GALLONS					KWH

[illegible] 2
Mineral Industry Surveys, Census, NEDS

[illegible]

Table 2.
Sulfur and Ash Content of Coal and Heating Oil

SOURCE	PERCENT SULFUR*					PERCENT ASH*		
	ANTHRACITE COAL	BITUMINOUS COAL	LIGNITE COAL	RESIDUAL OIL	DISTILLATE OIL	ANTHRACITE COAL	BITUMINOUS COAL	LIGNITE COAL
INDUSTRIAL		1.7		2.2	0.1		7.4	
COMMERCIAL INSTITUTIONAL		1.7		2.2	0.1		7.4	
RESIDENTIAL		1.7		2.2	0.1		7.4	
ELECTRICITY GENERATION								

DATA SOURCES NEDS FILE

BASE YEAR ~~1973~~

*SULFUR AND ASH CONTENT ARE GIVEN PER UNIT WEIGHT FOR COAL, PER UNIT VOLUME FOR OIL

SOLUTION 3-3

Estimate emissions from fugitive dust sources.

1. Agricultural tilling

Determine the precipitation-evaporation (PE) index from Fig. F-2.

$$PE = 118$$

Substitute this and the silt content into Eq. F-2:

$$E = \frac{(1.4)(45)}{(118/50)^2} = 11.3 \text{ lb/acre}$$

The total emissions are given by:

$$\text{Emissions} = (11.3)(194{,}000) = 2{,}192{,}200 \text{ lb} = 1096 \text{ tons}$$

Since the land is tilled only once per year, this is the total annual emission rate. A correction of 0.8 is applied since only 80% of the emissions are less than 30 μ and hence have the potential for long-range transport. The emission rate is then:

$$\text{Emissions} = (0.8)(1096) = 877 \text{ ton/yr}$$

2. Unpaved roads

Determine the mean annual number of days with 0.01 in or more of rainfall from Fig. F-1.

$$w = 130 \text{ days}$$

Substitute this along with the silt content and average speed into Eq. F-1:

$$E = (0.81)(12)\left(\frac{35}{30}\right)\left(\frac{365-130}{365}\right) = 7.3 \text{ lb/veh-mile}$$

The vehicle traffic is computed as:

$$(30 \text{ mi}) \times (60 \text{ veh/day}) = 1800 \text{ veh-miles/day}$$

The total emissions are given by:

$$\text{Emissions} = (7.3)(1800) = 13{,}140 \text{ lb/day} = 2{,}398 \text{ ton/yr}$$

A correction if 0.6 is applied to account for the particles less than 30 μ in diameter. The emission rate is then:

$$\text{Emissions} = (0.6)(2398) = 1439 \text{ ton/yr}$$

3. Heavy construction

Using Eq. F-4, the emission rate is:

1.2 (ton/acre of construction/month of activity) x 250 (acres) x 12 (months)

= 3600 ton/yr

SOLUTION 4-1

Estimate future emissions for the clay products industry in County X.

1. Determine the 1980 activity level.

   Baseline: $P_0 = 35{,}000 + 15{,}000 = 50{,}000$ tons/year of product.

   Growth factor: $G = 1 + .025 = 1.025$ per year.

   1980 Activity: $P_{1980} = (50{,}000)(1.025)^{1980-1973}$ from Eq. 4-13.

   1980 Emissions: $E_{1980} = (59{,}434)(\text{tons/yr}) \times 10\ (\text{lb/ton})$

   $= 594{,}340$ lb/yr = 297 ton/year of particulates from Eq. 4-14.

2. Perform intermediate calculation for 1982.

   $P_{1982} = P_{1980}\, G_{1980,1982} = (59{,}434)(1.025)^2 = 62{,}443$ tons/yr of product.

   $E_{1982} = (62{,}443)(\text{tons/yr}) \times (10\ \text{lb/ton})$

   $= 624{,}430$ lb/yr = 312 tons/yr of particulates.

3. Perform intermediate calculation for 1983.

   $(P_{1983})_{total} = P_{1982}\, G_{1982,1983} = (62{,}443)(1.025) = 64{,}004$ tons/yr of product.

   Disaggregate into existing and new and modified:

   $(P_{1983})_{\text{new + modified}} = (P_{1983})_{total} - P_{1982}$

   $= 64{,}004 - 62{,}443 = 1561$ tons/yr of product from Eq. 4-19.

   Compute emissions:

   $E_{1983} = (P_{1983})_{\text{new + modified}}\,(EF)_{new} + (P_{1983})_{existing}\,(EF)_{existing}$

   $= (1561)(4.5) + (62{,}443)(10)$

   $= 631{,}455$ lb/yr = 316 tons/yr of particulates.

Equation 4-25 can be used to compute this directly:

$$E_{1983} = P_0\, G^{10-1}[(10) + (G^1 - 1)(4.5)]$$

(ℓ=10, from 1973 to 1983)
(p=0)

$$= (50{,}000)(1.025)^9[10 + (1.025-1)(4.5)]$$

$$= 631{,}455 \text{ lb/yr} = 316 \text{ tons/yr of particulates}$$

4. Perform intermediate calculation for 1984.

$$P_{1984} = P_{1983}\, G_{1983,1984}$$

$$= (64{,}004)(1.025) = 65{,}604 \text{ tons/yr of product.}$$

$$E_{1984} = 638{,}657 \text{ lb/yr} = 319 \text{ tons/yr of particulates.}$$

(ℓ=10)
(p=1)

5. Perform calculation for 1985.

$$P_{1985} = P_{1984}\, G_{1984,1985}$$

$$= (65{,}604)(1.025) = 67{,}244 \text{ tons/yr of product.}$$

Disaggregate into existing and new and modified:

$$(P_{1985})_{\substack{\text{new +}\\ \text{modified}}} = (P_{1985})_{\text{total}} - (P_{1982} - P_{\substack{\text{retirement}\\ \text{in 1984}}})$$

$$= 67{,}244 - (62{,}443 - 15{,}000)$$

$$= 19{,}801 \text{ tons/yr of product.}$$

Note that the assumption is made that capacity additions will match retirements to maintain total output levels. Compute emissions:

$$E_{1985} = (P_{1985})_{\substack{\text{new +}\\ \text{modified}}} (EF)_n + (P_{1985})_{\text{existing}} (EF)_{\text{exist}}$$

$$= (19{,}801)(4.5) + (47{,}443)(10)$$

$$= 563{,}535 \text{ lb/yr} = 282 \text{ tons/yr of particulates.}$$

SOLUTION 5-1

Allocate clay products industry emissions using data from Problem 4-1.

1. Compute baseline particulate emissions for the existing point sources:

   Company ABC: 35,000 (tons of product/yr) x 10 (lb/ton)
   = 350,000 lb/yr = 175 tons/yr of particulates.

   Company DEF: 15,000 (tons of product/yr) x 10 (lb/ton)
   = 150,000 lb/yr = 75 tons/yr of particulates.

   Enter this data on Table 3.4-1 of Ref. 13 (Fig. 5-1) for 1973.

2. It is assumed that the plants are at full capacity, hence the 1980 emissions entered on Table 3.4-1 are the same as 1973. In 1985 one plant has retired, hence the emissions reflect only the continued operation of Plant ABC.

   If information on unused capacity is available, Table 3.4-1 can be used to record it.

3. In column (2) of Table 3.4-2 (Fig. 5-2) enter the total baseline year emissions for the entire county from the clay products industry (175 + 75 = 250 tons/yr). In column (9) enter the total emissions from the clay products industry in the county for 1980 and 1985 (calculation no. 1 and no. 5 from Solution 4-1, respectively).

4. In column (15) enter the expected emissions from existing sources in the forecast years. In 1980 both plants are assumed to remain in full operation; hence the emissions are the same as in the baseline year. In 1985 one plant has been shut down resulting in emissions of only 175 tons/yr (i.e., Company ABC only).

5. In column (21) enter the difference between columns (9) and (15). This represents emissions from new sources about which there is no specific locational information. These are the emissions that must be allocated.

6. Develop a distribution function based on growth in industrial land area. From the data in Appendix D the county's industrial land use will grow from 6035 acres in 1973 to 6983 acres in 1980. Of these 948 acres, 152 acres are expected in the Southwest Superdistrict (no. 14), 43 acres in the Tri-Cities Superdistrict (no. 15), 407 acres in the South Superdistrict (no. 16), and so forth for the other districts. The allocation proportions (AP) can be developed for this as follows:

$$AP_{14} = 152/948 = 0.160$$

$$AP_{15} = 43/948 = 0.045$$

$$AP_{16} = 407/948 = 0.429$$

etc.

Thus, for example, 16% of the new source growth can be allocated to Superdistrict 14. Enter these allocation proportions into column (5) of Table 3.4-3 (Fig. 5-3).

7. Multiply the county total new source emissions (column (21)) of Table 3.4-2 by the allocation proportion for each subarea (column (5)) of Table 3.4-3 and enter into column (6) of Table 3.4-3.

8. Summarize the results on Table 3.4-4 (Fig. 5-4). In column (4) enter the emissions from existing sources in each forecast year for each subarea (from column (7) of Table 3.4-1). In column (10) enter the emissions from new sources (from column (6) of Table 3.4-3). In column (16) sum columns (4) and (10) for the subarea total emissions.

Table 5-1

Point Source Industrial Process Emission

A. County X
B. Year
C. Allocation Order 1, 2, and 3

	INDUSTRIAL PROC CAT (1)	SOURCE IDENTIFICATION (2) NAME	(3) PROCESS	(4) SUBAREA	COORD (5) X	COORD (5) Y	PROCESS EMISSION FORECAST (TONS/YR) (6) F*	(7) CONT	(8) EMIS	(9) CONT	(10) EMIS	(11) CONT	(12) EMIS	(13) CONT	(14) EMIS	(15) CONT	(16) EMIS	(17) EMIS**
1973	Clay Prod	ABC	3-04 -003	16	X1	Y1			175									
	Clay Prod	DEF	3-04 -003	15	X2	Y2			75									
1980	Clay Prod	ABC		16	X1	Y1			175									
	Clay Prod	DEF		15	X2	Y2			75									
1985	Clay Prod	ABC		16	X1	Y1			175									
	Clay Prod	DEF		15	X2	Y2			0									

*Growth Factor

**Employment

A. County X
B. Year
C. Allocation Order 2 and 3

	INDUSTRIAL PROD CAT (1)	BASELINE YR - EXISTING POINT SOURCES						[illegible]							[illegible]						[illegible]										
		(2) PART	(3) NO_x	(4) SO_x	(5) HC	(6) CO	(7) EMI	(1)	PART	NO_x	SO_x	HC	CO	EMI	(1) PART	NO_x	SO_x	HC	CO	EMI	PART CONT	PART EMI	NO_x CONT	NO_x EMI	SO_x CONT	SO_x EMI	HC CONT	HC EMI	CO CONT	CO EMI	EMI CONT	EMI
1980	Clay Prod	250							297						250							47									
1985	Clay Prod	250							282						175							107									
	COUNTY TOTAL																														

SOLUTION 5-1 (Cont'd)

Table 3.4-3

Process Emissions by Process Category and Subarea

A. County X
B. Subarea
C. Year
D. Allocation Order 2 and 3

Subarea/year	INDUSTRIAL PROC CAT (1)	TOTAL EMP (2)	POINT SOURCE EMP (3)	NEW SOURCE EMP (4)	EAP* (5)	NEW SOURCE EMISSIONS (TONS/YR) PART (6)	NO_x (7)	SO_x (8)	HC (9)	CO (10)
14/1980	Clay Products				.160	8				
15/1980	Clay Products				.045	2				
16/1980	Clay Products				.429	20				
14/1985	Clay Products				.155	17				
15/1985	Clay Products				.054	6				
16/1985	Clay Products				.357	38				
SUBAREA TOTAL										

*Employment Allocation Proportion = $\frac{\text{Subarea Category New Source Employment}}{\text{Total Category New Source Employment}}$

[a] Allocation Proportion based on change in industrial land use rather than employment. See data in Appendix D.

Table 1-4-4

Industrial Point and New Source Process Emissions - Oklahoma Summer

A. County X
B. Subarea
C. Year
D. Allocation Order 1, 2, and 3

Subarea/year	SUBAREA (1)	POINT SOURCE EMISSIONS (2) No. of SOURCES	(3) [illegible]	(4) PART	[illegible]	[illegible]	[illegible]	[illegible]	NEW SOURCE EMISSIONS [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOTAL EMISSIONS [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
14/1980	Clay Products	0		0						8						8				
15/1980	Clay Products	1		75						2						77				
16/1980	Clay Products	1		175						20						195				
14/1985	Clay Products	0		0						17						17				
15/1985	Clay Products	0		0						6						6				
16/1985	Clay Products	1		175						38						213				

SOLUTION 5-2

Develop a grid system for the portion of County X shown.

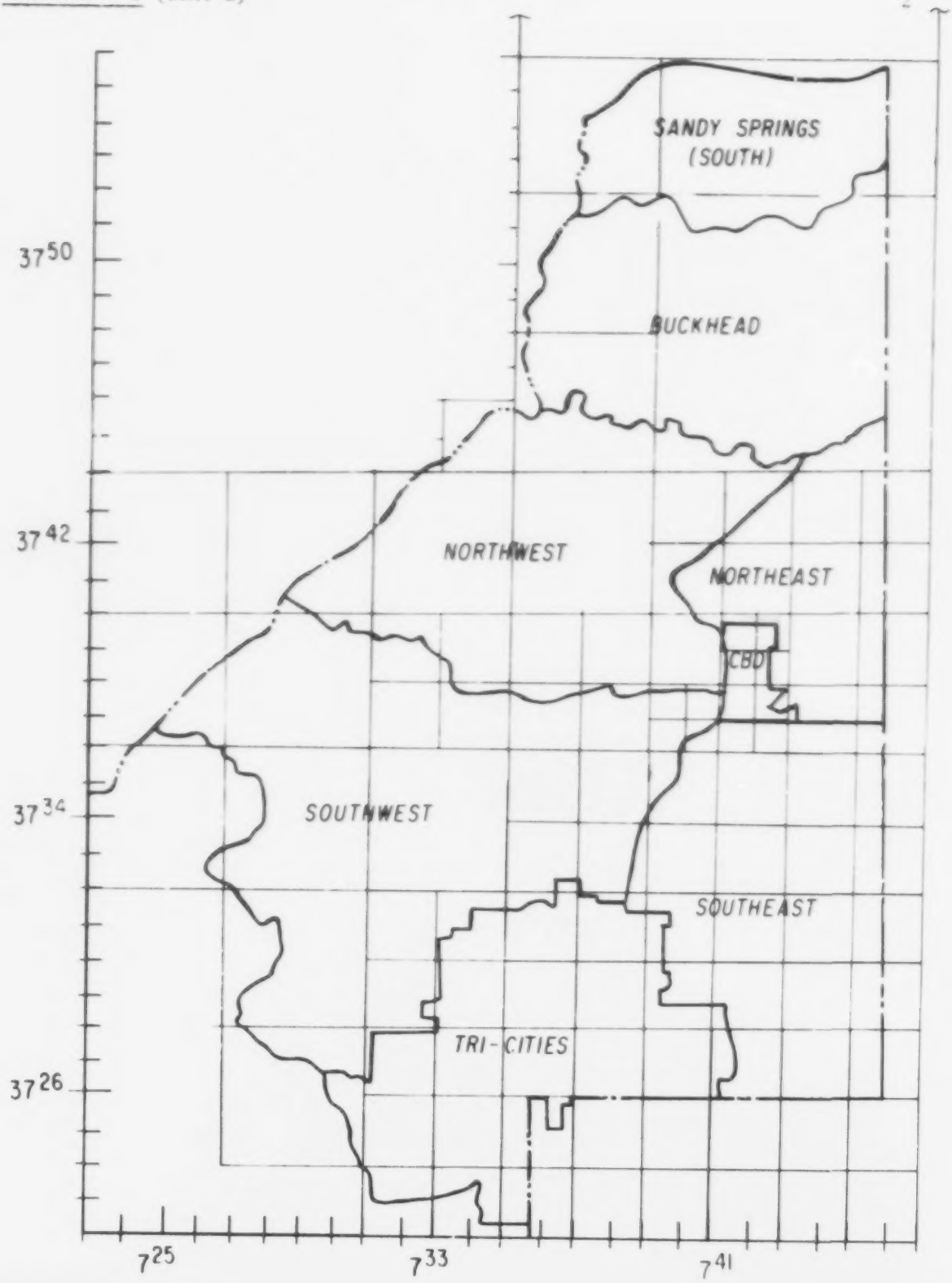
1. Using the coordinate system on the figure, first draw in a rectangular set of grids 8 km on a side.

2. Begin subdividing these wherever a boundary line intersects one of the grids.

3. Continue subdividing until the smallest grid is 1 km x 1 km or until the grid contains only one subarea.

4. In fringe areas it may be desirable to leave larger grids to keep the total number manageable.

SOLUTION 5-2 (Cont'd)



SOLUTION 5-2. Master Grid Over Portion of County X

SOLUTION 5-3

Determine area fractions for the Northwest Superdistrict. (Grid coordinates are measured at the lower left-hand corner.)

1. Grid cells (735, 3738), (735, 3740), and (737, 3738) are contained entirely within the Superdistrict. They are 4, 16, and 4 km^2, respectively. Since the total area of the Superdistrict is 77 km^2, these grids represent 4/77, 16/77, and 4/77 of the area. The fractions are, therefore, .052, .207, and .052, respectively.

2. The remaining grids may be subdivided into 1 km^2 cells. Each one that is wholly contained in the Superdistrict is 1/77 of the area or has an area fraction of 0.013. The cells that are across boundaries may be "eyeball approximated" as to what portion lies in the Superdistrict. The cells are then summed to get the area fraction for the whole grid.

3. The estimated area fractions are as follows:

Grid	Area fraction of Northwest Superdistrict
727, 3736	.012
727, 3740	.037
731, 3738	.021
731, 3740	.191
733, 3736	.008
733, 3738	.047
733, 3744	.023
735, 3736	.012
735, 3738	.052
735, 3740	.207
735, 3744	.104
737, 3736	.009
737, 3738	.052
739, 3737	.004
739, 3738	.047
739, 3740	.025
739, 3742	.050
739, 3744	.064
740, 3737	.004
741, 3737	.001
741, 3738	.004
741, 3739	.001
741, 3742	.025

Thus, 1.2% of the emissions computed for the Northwest Superdistrict will be allocated to master grid (727, 3736).

SOLUTION 7-1

Determine the magnitude, spatial and temporal extent, and source contributions to the County X air quality problem.

1. Within County X are isolated violations of the primary NAAQS for particulates in 1975. These violations are caused by a few large point sources within the county near which the computed concentrations are well above the standard. In the central portion of the county is a widespread area of violations of the secondary standard caused by the aggregation of point and area sources located there. Violations of both the primary and secondary standards extend beyond the county's boundary. Attainment of both standards is a problem.

2. The area affected by violations of the standards will have increased by 1980 and 1985, indicating that a maintenance problem also exists. The growth in extent of the violations is largely arrested between 1980 and 1985, possibly due to the effectiveness of the control equipment required during that period by NSPS. By 1985, violation of the secondary standard covers a large area beyond the county's boundaries; the sources within the county will still be the overwhelming cause. The primary standard will be exceeded widely over the central part of the county, while two isolated areas of violations remain. In contrast to the isolated violations of the primary standard in 1975 that are caused almost entirely by a few stone quarries, the widespread area of violation by 1985 will be caused by a mixture of industries.

3. Area sources appear to be only of secondary importance in these results.

SOLUTION 8-1

Develop a list of potential control strategies for County X.

1. Prior to considering the development of new control programs, it must be determined whether compliance with existing regulations will attain and maintain NAAQS. Of the five receptors listed on Table 7-1 Receptors 119, 151, and 233 violate the secondary annual guideline in 1975. Of the major contributing sources only concrete plants #4 and #6 are in compliance with existing regulations. Neglecting the change in total emissions resulting from overall compliance, the percentage reduction in a source's contribution to computed air quality values can be approximated by:

$$\% \text{ Reduction} = \left(1 - \frac{\text{Allowable emissions}}{\text{Baseline emissions}}\right) \times \left(\frac{\% \text{ contribution to}}{\text{computed air quality}}\right)$$

For example, the approximate % reduction at Receptor 119 that would result from compliance at stone quarry #1 is:

$$\% \text{ Reduction} = \left(1 - \frac{6265}{7620}\right) \times 1.7 = 0.30\%.$$

This calculation is repeated for all sources out of compliance:

Source		Approximate Reduction in Calculated Concentration Achieved by Source Compliance (%)		
		Receptor 119	Receptor 151	Receptor 233
Stone Quarry	#1	0.30	0.46	0.53
	2		0.52	2.65
	3		0.69	
	4	0.52	0.70	0.66
	5	11.83	4.13	5.44
	6		0.61	0.44
	7		0.44	0.48
Steel Mill	#1	0.14	0.49	0.20
	2	0.08	0.51	0.10
Lead Smelter		1.38	2.17	2.66
Steam Plant	#1	1.68	1.15	4.20
	2	0.68	1.23	1.23
Brick Plant	#1	3.53		1.18
	2			0.98
Concrete Plant	#4	0.00	0.00	0.00
	6	0.00	0.00	0.00
Total		20	13	21
Needed for NAAQS Attainment:		15	17	22

SOLUTION 8-1 (Contd.)

Receptor #119 appears likely to attain the NAAQS under compliance conditions. (Stone Quarry #5 alone provides about 12% of the needed 15% reduction.) Receptor #151 will not attain the NAAQS by compliance only. Receptor #233 is a borderline case requiring more detailed analysis for an accurate determination.

2. Since compliance will not guarantee the overall percentage reduction necessary for NAAQS attainment, additional programs will be necessary. As emissions are projected to increase in the future, a maintenance problem will also exist.

3. Area sources, even if reduced to zero emissions, would provide only an additional 4.4% reduction at Receptor #151 in 1975. This additional reduction would make NAAQS attainment a borderline situation. Since elimination of the entire area source contribution is infeasible, additional programs for both point and area sources should be considered along with increased enforcement.

4. The table of percentage reductions indicates that the stone quarries have the largest impact at compliance. In a complete analysis, this expectation would need to be verified at the other receptor points with NAAQS attainment problems. Since even compliance emissions will not provide NAAQS attainment, retrofit of existing sources with technological controls sufficient to attain NSPS or better control efficiencies might be considered. Requiring increased control efficiencies at selected sources or in selected source categories could be investigated. In an extreme situation, phaseout of the quarrying operations might be considered.

5. The reductions required in 1980 and 1985 are larger than those required in 1975 due to anticipated growth. This is true at all the receptors listed in Table 7-1. If the imposition of technological controls sufficient to attain and maintain NAAQS proves to be infeasible, this result indicates the need for programs that would either limit or redistribute the projected growth and perhaps a portion of the existing emissions. Among others, an emission density zoning scheme provides a strategy for determining the quantity of emissions that can be tolerated in certain areas. This approach does not, however, give detailed tactics for determining how to reach the limits or effect the redistribution.

6. On the basis of the information in Table 7-1, several conclusions concerning potential control strategies can be reached:

   Increased enforcement should be considered with stone quarries a possible first priority,

Retrofit of existing point sources to NSPS or better emission levels can be considered, possibly on a selective basis,

In view of the additional problems caused by projected growth, limits on emissions in various areas must be determined and strategies developed to meet these limits, and

The possibility for control of area sources should be assessed.

A detailed breakdown of the major area source contributions is given in Table 7-2 for Receptor #151. Neither transportation nor residential/commercial/institutional space heating contributes to the attainment problem or is projected to be a contributor in the future. (The small industrial contributions in 1980 and 1985 represent the difference between the industrial area specific and regional industry specific growth projections that were not allocated to specific point source categories.) Thus, a transportation control plan is not necessary and strategies aimed at reducing emissions from space heating would have little impact. In a complete analysis, this conclusion might not be true for all receptors and a transportation control plan, for example, might be a useful strategy in another area of the study region. To determine the specific nature of the area source control strategies, the nature of the miscellaneous contribution needs to be determined. This information, in a real case, would be available in the emissions inventory. Typical sources include: unpaved roads, incineration, construction, or agricultural burning.

SOLUTION 8-2

Determine the impact of various technological controls on the clay products industry.

(a) Prior to beginning the emission projections, the period over which the retrofit will take place must be determined. A three-year retrofit program is assumed here beginning in 1980 and completed at the end of 1982. New and modified capacity will also be assumed to meet the retrofit level. The shutdown at Company DEF will produce no change in projected emissions. One facility will simply be replaced by another of equal capacity and equivalent control efficiency. Since all sources will be controlled to the NSPS level by 1982, the imposition of the NSPS in 1983 will have no effect.

1. Determine 1979 activity level.

Baseline: $P_o = 35{,}000 + 15{,}000 = 50{,}000$ T/yr of product

Growth factor: $G = 1 + .025 = 1.025$ per year

1979 activity: $P_{1979} = (50{,}000)(1.025)^{1979-1975}$

$= 57{,}985$ T/yr

2. Perform calculation for 1980.

Retrofit rate: Assume a uniform rate. One-third of the capacity existing at the end of 1979 is retrofitted each year for three years:

Retrofit rate = 1/3 x 57985 = 19328 T/yr

$$(P_{1980})_{total} = P_{1979} \times G_{1979,1980} = 57{,}985(1.025)$$

$$= 59{,}434 \text{ T/yr}$$

Disaggregate in retrofitted, existing unretrofitted, and new or modified:

$$(P_{1980})_{\substack{new + \\ modified}} = (P_{1980})_{total} - P_{1979}$$

$$= 59{,}434 - 57{,}985 = 1{,}449 \text{ T/yr.}$$

$$(P_{1980})_{retrofitted} = 19{,}328 \text{ T/yr.}$$

$$(P_{1980})_{\substack{existing \\ unretrofitted}} = P_{1979} - (P_{1980})\ retrofitted$$

$$= 57985 - 19328 = 38{,}657 \text{ T/yr.}$$

Calculate 1980 emissions:

$$E_{1980} = [(P_{1980})_{\substack{new + \\ modified}} + (P_{1980})_{retrofitted}] \times (EF)_{new}$$

$$+ (P_{1980})_{\substack{existing \\ unretrofitted}} \times (EF)_{old}$$

$$= (1449 + 19{,}328)(4.5) + (38{,}657)(10)$$

$$= 480{,}066 \text{ lb/yr} = 240 \text{ T/yr of particulates.}$$

This result may be compared to the 297 T/yr of particulates calculated as emitted in Problem 4-1 where no retrofit had occurred in 1980 and new or modified sources were not subject to control.

The calculation can also be done by modifying Eq. (4-17). The assumptions in this formulation were that new and modified sources meet the new emission standard. In the first year, a retrofit program implies that an additional fraction 1/m of the total activity occurs at sources meeting the new standard. Thus,

$$E_\ell = P_o G^{\ell-1}[(EF)_e(1 - \frac{1}{m}) + (G - 1 + \frac{1}{m})(EF)_n]$$

$$= 50{,}000(1.025)^6\ [10(2/3) + (1.025 - 1 + 1/3)\ 4.5]$$

$$= 480{,}065 \text{ lb/yr} = 240 \text{ T/yr}$$

as found above.

3. Perform calculation for 1985.

By 1985, all sources will be required to meet NSPS either as new or modified sources subject to NSPS or as a result of the retrofit program completed in 1982.

$$P_{1985} = P_{1980} \times G_{1973,1985} = 50{,}000(1.025)^{12}$$

$$= 67{,}244 \text{ T/yr}$$

$$E_{1985} = (P_{1985})(EF)_{new} = 67{,}244 \times 4.5$$

$$= 302{,}598 \text{ lb/yr} = 151 \text{ T/yr of particulates.}$$

This may again be compared with result of Problem 4-1. There, 282 T/yr of particulate emissions were projected for 1985 but only about 30% of the activity was subject to the stringent NSPS.

(b) As above, assume that new and modified sources must meet the most stringent applicable standard; that is, NSPS beginning in 1983 and the retrofit standard prior to 1983. The retrofit program is to be completed in three years by the end of 1982.

1. Determine 1979 activity level.

$$P_{1979} = 57{,}985 \text{ T/yr}$$

2. Perform calculation for 1980.

The calculation proceeds as in (a-2) except that $(EF)_{new} = \frac{10+4.5}{2}$ = 7.25 lb/T.

$$E_{1980} = [(P_{1980})_{\substack{\text{new +}\\ \text{modified}}} + (P_{1980})_{\text{retrofitted}}] \times (EF)_{new}$$

$$+ (P_{1980})_{\substack{\text{existing}\\ \text{unretrofitted}}} \times (EF)_{old}$$

$$= (1449 + 19{,}328)(7.25) + (38{,}657)(10)$$

$$= 537{,}208 \text{ lb/yr} = 269 \text{ T/yr of particulates.}$$

3. Perform calculation for 1985.

Determine 1982 activity level:

$$P_{1982} = 50{,}000(1.025)^{1982-1973} = 62{,}443 \text{ T/yr.}$$

Determine 1985 activity level:

$$(P_{1985})_{total} = 67{,}244 \text{ T/yr.}$$

Disaggregate in existing (retrofitted) and new or modified taking the retirement of Company DEF into account:

SOLUTION 8-2 (Contd.)

$$(P_{1985})_{\substack{\text{new +}\\ \text{modified}}} = (P_{1985})_{\text{total}} - (P_{1982} - P_{\substack{\text{retirement}\\ \text{in 1984}}})$$

$$= 67{,}244 - (62{,}443 - 15{,}000)$$

$$= 19{,}801 \text{ T/yr.}$$

$$(P_{1985})_{\substack{\text{existing}\\ \text{retrofitted}}} = (P_{1979}) + (P_{1982} - P_{1979} - P_{\substack{\text{retirement}\\ \text{in 1984}}})$$

$$= 62{,}443 - 15{,}000 = 47{,}443 \text{ T/yr.}$$

$$(E_{1985}) = (P_{1985})_{\substack{\text{new +}\\ \text{modified}}} \times (EF)_{NSPS}$$

$$+ (P_{1985})_{\substack{\text{existing}\\ \text{retrofitted}}} \times (EF)_{\text{retrofit}}$$

$$= (19{,}801)(4.5) + (47{,}443)(7.25)$$

$$= 433{,}066 \text{ lb/yr} = 217 \text{ T/yr of particulates.}$$

As expected, this result lies between the 151 T/yr projected in (a) above where all sources met NSPS standards in 1985 and the projection of Problem 4-1 where only the new/modified sources met NSPS and no retrofit program was in effect.

(c) Assume the program to induce accelerated phaseout begins in 1980. Considering only projected emissions, the effects of accelerated phaseout and retrofit are equivalent. Company DEF whose plans include a phaseout in 1984 is unlikely to change. Company ABC, however, develops a seven-year plan for retiring 1/7 of its current production each year beginning in 1980 and ending in 1986. As part of the accelerated phase-out plan, any capacity converted prior to the effective date of the NSPS, 1983, will only need to meet the 7.25 lb/T emission limit. However, this limit will apply to all new or modified capacity and not just that replacing phased out capacity.

1. Determine 1979 activity level.

$$P_{1979} = 57{,}985 \text{ T/yr.}$$

2. Perform calculation for 1980.

$$(P_{1980})_{total} = 59{,}434 \text{ T/yr}$$, as in the last two examples.

Disaggregate into existing and new or modified taking into account the phaseout at Company ABC:

Capacity per year phased out at ABC = 1/7 x (Current production)

= 1/7 x 35,000 = 5,000 T/yr phaseout.

$$(P_{1980})_{phased\ out} = 5{,}000(1980-1979) = 5{,}000 \text{ T/yr phased out at ABC.}$$

$$(P_{1980})_{\substack{new\ +\\ modified}} = (P_{1980})_{total} - [(P_{1979}) - (P_{1980})_{phased\ out}]$$

$$= 59{,}434 - 57{,}985 + 5{,}000$$

$$= 6{,}449 \text{ T/yr.}$$

$$(P_{1980})_{existing} = (P_{1980})_{total} - (P_{1980})_{\substack{new\ +\\ modified}}$$

$$= 59{,}434 - 6{,}449 = 52{,}985 \text{ T/yr.}$$

Calculate 1980 emissions:

$$E_{1980} = (P_{1980})_{\substack{new\ +\\ modified}} \times (EF)_n + (P_{1980})_{existing} \times (EF)_o$$

$$= 6{,}449 \times 7.25 + 52{,}985 \times 10$$

$$= 576{,}605 \text{ lb/yr} = 288 \text{ T/yr of particulates.}$$

3. Perform interim calculation for 1982.

$$(P_{1982})_{total} = 62{,}443 \text{ T/yr.}$$

Disaggregate in new or modified and existing, taking the retirement at ABC into account:

$$(P_{1982})_{\substack{phased\ out\\ at\ ABC}} = 5000(1982-1979) = 15{,}000 \text{ T/yr phased out at ABC.}$$

$$(P_{1982})_{\substack{\text{new +}\\ \text{modified}}} = (P_{1982})_{\text{total}} - [P_{1979} - (P_{1982})_{\substack{\text{phased out}\\ \text{at ABC}}}]$$

$$= 62{,}443 - 57{,}985 + 15{,}000$$

$$= 19{,}458 \text{ T/yr subject to } 7.25 \text{ lb/T limit.}$$

We will assume that all further growth takes place at new or modified facilities subject to NSPS. Thus, all further growth and retirements will be subject to NSPS and capacity either new, modified, or retired between 1980 and the end of 1982 will be subject to the interim emission limit of 7.25 lb/T until it is modified or replaced at some time beyond 1986.

4. Perform calculation for 1985.

$$(P_{1985})_{\text{total}} = 67{,}244 \text{ T/yr.}$$

Disaggregate into existing, new/modified subject to NSPS and retired subject to interim standard, taking the retirement at Company DEF into account:

$$(P_{1985})_{\substack{\text{phased out}\\ \text{total ABC}}} = 5{,}000(1985\text{-}1979) = 30{,}000 \text{ T/yr phased out at ABC.}$$

$$(P)_{\substack{\text{ABC phased out}\\ 1983\text{-}1985}} = (P_{1985})_{\substack{\text{phased out}\\ \text{total ABC}}} - (P_{1982})_{\substack{\text{phased out}\\ \text{at ABC}}}$$

$$= 30{,}000 - 15{,}000 = 15{,}000 \text{ T/yr}$$

phased out at ABC and subject to NSPS.

$$(P_{1985})_{\substack{\text{new +}\\ \text{modified}}} = (P_{1985})_{\text{total}} - (P_{1982} - P_{\substack{\text{retirement DEF}\\ \text{in 1984}}} - P_{\substack{\text{ABC phased out}\\ 1983\text{-}1985}})$$

$$= 67{,}244 - 62{,}443 + 15{,}000 + 15{,}000$$

$$= 34{,}801 \text{ T/yr of production subject to NSPS.}$$

$$(P_{1985})_{\text{existing}} = (P_{1985})_{\text{total}} - (P_{1985})_{\substack{\text{new +}\\ \text{modified}}} - (P_{1982})_{\substack{\text{new +}\\ \text{modified}}}$$

$$= 67{,}244 - 34{,}801 - 19{,}458$$

$$= 12{,}985 \text{ T/yr.}$$

SOLUTION 8-2 (Contd.)

Calculate 1985 emissions:

$$E_{1985} = (P_{1985})_{existing} \times (EF)_o + (P_{1982})_{\substack{new + \\ modified}} \times (EF)_n$$

$$+ (P_{1985})_{\substack{new + \\ modified}} \times (EF)_{NSPS}$$

$$= (12{,}985) \times (10) + (19{,}458) \times (7.25) + (34{,}801)(4.5)$$

$$= 427{,}525 \text{ lb/yr} = 214 \text{ T/yr of particulates.}$$

SOLUTION 8-3

Estimate the emission reduction in County X from using central district heating.

1. Since the emission factors for individual homes and the central plants are equal, the decrease in emissions expected from a gas central plant, ΔE, will be:

$$\Delta E = EF_g \times (G_i - G_c) \quad (1)$$

where EF_g is the gas emission factor, and G_i and G_c are the consumption rates for individual homes and the central plant, respectively.

Due to the increased efficiency of the plant:

$$G_c = (1-.15)G_i = .85\ G_i \quad (2)$$

$$\text{and } \Delta E = EF_g \times (G_i - .85\ G_i) = .15(EF_g) \times (G_i) \quad (3)$$

G_i can be found from the total heat required for the homes, the heating value of gas, and the individual home fuel efficiency.

$$\text{Total heat required} = (50.7 \times 10^6 \text{ Btu/yr/home}) \times (10{,}000 \text{ homes})$$

$$= 50.7 \times 10^{10} \text{ Btu/yr} \quad (4)$$

$$G_i = (50.7 \times 10^{10} \text{ Btu/yr}) : (1050 \text{ Btu/ft}^3 \times 0.8)$$

$$= 6.04 \times 10^8 \text{ ft}^3\text{/yr} \quad (5)$$

The factor 0.8 corrects for the fuel efficiency of the individual home heating unit.

From Eq. (3):

$$\Delta E = .15 \times 10 \text{ lb}/10^6 \text{ ft}^3 \times 6.04 \times 10^8 \text{ ft}^3\text{/yr}$$

$$= 910 \text{ lb/yr.}$$

This is less than 1/2 T/yr and is negligible in the emissions inventory even considering the change from a distributed area source to a single point source. However, the gas central plant may still provide an attractive alternative when considered as a means of saving natural gas.

2. The control efficiency η that would be necessary for an oil-fired central plant be found from:

$$E_o(1-\eta) = (EF_g) \times G_i \tag{6}$$

$$\text{or } \eta = \frac{E_o - (EF_g) \times G_i}{E_o} \tag{7}$$

E_o are the uncontrolled particulate emissions from the central plant when oil is used. The right-hand side of Eq. (6) are the emissions from the individual homes that act as a ceiling on the plant emissions.

The emissions E_o can be found by calculating the oil consumption required to produce the needed heat and applying the appropriate oil emission factor EF_o.

$$\text{Heat required from oil} = G_c \times (\text{Gas heating value}) \times 95/89 \tag{8}$$

The last factor corrects for the decreased efficiency of oil compared to gas. From Eq. (2) and (5),

$$\begin{aligned}\text{Heat required from oil} &= .85\ G_i \times (\text{Gas heating value}) \times 95/89 \\ &= .85 \times 6.04 \times 10^8\ ft^3/yr \times 1050\ Btu/ft^3 \times 95/89 \\ &= 5.75 \times 10^{11}\ Btu/yr \end{aligned} \tag{9}$$

The oil consumption can now be found.

$$\begin{aligned}\text{Oil consumption} &= (\text{Heat required}) \div (\text{Oil heating value}) \\ &= (5.75 \times 10^{11}\ Btu/yr) \div (150{,}000\ Btu/gal) \\ &= 3.83 \times 10^6\ gal/yr \end{aligned} \tag{10}$$

Then,

$$\begin{aligned}E_o &= EF_o \times (\text{Oil consumption}) \\ &= 23\ lb/10^3\ gal \times 3.83 \times 10^6\ gal/yr \\ &= 8.81 \times 10^4\ lb/yr \end{aligned} \tag{11}$$

Eq. (7) can now be used to find the required control efficiency:

$$\eta = \frac{8.81 \times 10^4\ lb/yr - 10\ lb/10^6\ ft^3 \times 6.04 \times 10^8\ ft^3/yr}{8.81 \times 10^4\ lb/yr}$$

$$= 93\%$$

This degree of control is within the range available with several particulate control devices. Whether such a system would be feasible on a central plant of this size requires further investigation.

SOLUTION 8-4

Develop an emission quota strategy for County X.

1. The percentage reduction in concentration needed to attain the 60 $\mu g/m^3$ secondary guideline is:

$$Preq = \frac{80 - 60}{80 - \text{Background}} \times 100 = \frac{80 - 60}{80 - .43 \times 80} \times 100 = 44\%$$

Assuming proportional reduction applies, the air quality contribution of each subarea will decrease in proportion to the decrease in emissions in that area.

2. One way of achieving the 44% overall reduction is thus to set an emission quota 44% below present emissions in each subarea:

$$(EQ)_i = E_i \times (1 - Preq) = .56\ E_i$$

where $(EQ)_i$ and E_i are the emission quota and subarea emissions, respectively, for the ith subarea. The emission quotas in this uniform reduction scheme are presented in the attached table. In this scheme, the overall emission reduction required by an aggregate proportional model should be equivalent to the reduction resulting from the imposition of the quotas:

$$E_{total} = \sum^{T} E_i = 135{,}580 \text{ T/yr.}$$

$$\text{Reduction needed} = .44 \times E_{total} = 59{,}655 \text{ T/yr.}$$

$$\text{Reduction from quotas} = 135{,}580 - 75{,}925 = 59{,}655 \text{ T/yr.}$$

This confirms the emission quota calculations.

3. The air quality impact of each subarea can be determined:

$$(AQ)_i = (\%\ \text{Contribution to air quality})_i \times (\text{Air quality})$$

The unit impact of 10,000 T/yr. of emissions from subarea i is then:

$$I_i = (AQ)_i \times \frac{10{,}000}{E_i}$$

$$= (\% \text{ Contribution to air quality})_i \times (\text{Air quality}) \times \frac{10{,}000}{E_i}$$

Note that this assumes a simple proportional model which applies to each subarea.

For example, $I_1 = .01 \times 80 \times \frac{10{,}000}{14{,}500} = 0.55 \frac{\mu g/m^3}{10^4 \text{ T/yr.}}$

These unit impacts are given on the table.

By using these unit impacts, tradeoffs can be made between subareas and the effects of various alternative strategies assessed. Under the uniform emission quota strategy, emissions in all subareas need to be decreased and this could potentially limit growth and development. A strategy allowing greater overall emissions while still maintaining NAAQS at receptor X can easily be found. For example, require the air quality impact of each subarea on X to be the same:

$$(AQ)_i = \frac{60 - \text{Background}}{11} = \frac{60 - 34.4}{11} = 2.33 \ \mu g/m^3 \text{ from each subarea}$$

$$(EQ)_i = \frac{(AQ)_i}{I_i} \times 10{,}000 = \frac{(2.33) \times 10{,}000}{I_i} = \frac{23{,}300}{I_i}$$

For subarea 1,

$$(EQ)_1 = \frac{23{,}300}{.55} = 42{,}360 \text{ T/yr. of particulates}$$

The emission quotas in this scheme are also presented in the table.

These emission quotas can be calculated by using the proportional model and the target air quality impact (2.33 $\mu g/m^3$) directly without using the unit impacts I_i. For example, in subarea 2:

$$(EQ)_2 = (E)_2 + (E)_2 \times \frac{2.33 - (AQ)_2 \text{ baseline}}{(AQ)_2 \text{ baseline}}$$

$$= 11{,}890 \left(1 - \frac{2.33 - 2.4}{2.4}\right) = 11{,}540 \text{ T/yr. of particulates.}$$

This result agrees with the results already obtained to within the roundoff error.

This scheme represents a substantial increase in emissions over those allowed in the uniform reduction scheme and even a slight increase over the baseline emissions. It does, however, penalize subareas like #6 and #7 with relatively large impacts on X. These subareas are probably close to the receptor X. That this scheme satisfies the air quality constraint (NAAQS attainment) at X can be verified:

$$(AQ)_X = \sum (EQ)_i \times \frac{I_i}{10,000} + \text{Background}$$

$$= (42,360) \times \frac{.55}{10,000} + (11,530) \times \frac{2.02}{10,000} + \ldots + 34.4 = 60\ \mu g/m^3$$

4. To avoid unfair reductions, a limit, say 75%, can be placed on the maximum emission reduction required in any subarea. The percentage reductions required by the uniform impact quotas are shown on the table. Percentage increases are left blank. Only subarea #6 is required to reduce emissions more than 75%:

$$(\text{Preq})_{\text{Subarea 6}} = \frac{3,000 - 437}{3,000} \times 100 = 85.4\%$$

If the maximum reduction is to be 75%, the modified emission quota for subarea 6 is:

$$(EQ)_6 = (1 - .75) \times (3,000) = 750 \text{ T/yr. of particulates}$$

This increase in emissions causes a change in air quality Δ (AQ) at X =

$$\Delta (AQ)_{X,6} = \frac{\Delta (EQ)_6}{10,000} \times I_6 = \frac{(750 - 437)}{10,000} \times 53.33$$

$$= 1.67\ \mu g/m^3$$

This must be compensated by decreases in emissions in other subareas. If the decrease Δ E is equal in all subareas:

$$\Delta (AQ)_X\ (1 - 5,\ 7 - 11) = \sum_{i \neq 6} \frac{\Delta E}{10,000} \times I_i$$

$$= \frac{\Delta E}{10,000} \sum_{i \neq 6} I_i = \frac{\Delta E}{10,000} X (35.63) = 1.67.$$

ΔE = 469 T/yr. of emissions.

Thus, the modified emission quota in, for example, subarea 3 is:

$$(EQ)_3 = (EQ)_{3\ \text{uniform impact}} - \Delta E = 7,520 - 469 = 7,050 \text{ T/yr.}$$

These modified emission quotas are presented in the table. Again the air quality constraint may be checked:

$$(AQ)_X = \sum_i (EQ)_i X \frac{I_i}{10,000} + \text{Background}$$

$$= (41,890) X \frac{.55}{10,000} + 11,060 X \frac{2.02}{10,000} + \ldots + 34.4 = 60 \ \mu g/m^3$$

This emission quota scheme allows fewer emissions than the equal impact scheme but still substantially more than the uniform reduction scheme. In total allowable emissions it is almost the same as the total baseline emissions but represents a substantial redistribution of emissions.

5. As a final alternative, allow emissions in the three subareas with the greatest emissions to expand by 10%. These may represent the heavy industrial areas. In the three areas with the lowest emissions (perhaps parks or undeveloped land) require a 75% emission reduction. In the remaining five areas require the same percentage change necessary to attain 60 $\mu g/m^3$ at X. The growth subareas are #1, 4, and 11; the clean subareas are #5, 6, and 8. For example,

$$(EQ)_1 = (1 + .10) X (14,500) = 15,950 \text{ T/yr. of particulates and}$$

$$(EQ)_5 = (0.25) X (1,100) = 275 \text{ T/yr. of particulates.}$$

Calculate the air quality contribution of the six designated subareas:

$$(AQ)_{\text{Designated}} = \sum_{\substack{\text{Designated} \\ \text{Subareas}}} \frac{(EQ)_{\text{Designated}} X I_i}{10,000}$$

$$= \frac{15,950 X .55}{10,000} + \frac{42,570 X 1.45}{10,000} + \cdots = 13.41 \ \mu g/m^3 \text{ at X.}$$

The air quality at X must be 60 $\mu g/m^3$ =

$$(AQ)_X = (AQ)_{\text{Undesignated}} + (AQ)_{\text{Designated}} + \text{Background}$$

$$= (AQ)_{\text{Undesignated}} + 13.41 + 34.4 = 60\ \mu g/m^3.$$

$(AQ)_{\text{Undesignated}} = 12.19\ \mu g/m^3$ allowed from the 5 undesignated subareas.

These five subareas presently contribute

$$(AQ)_{\substack{\text{Undesignated}\\ \text{baseline}}} = 2.4 + 1.6 + 8.8 + 3.2 + 3.2 = 19.2\ \mu g/m^3$$

Thus, an emission reduction will be needed in these subareas.

Using the proportional model:

$$(\text{Preq})_{\text{Undesignated}} = \frac{(AQ)_{\text{Undesignated}} - (AQ)_{\substack{\text{Undesignated}\\ \text{baseline}}}}{(AQ)_{\substack{\text{Undesignated}\\ \text{baseline}}}} \times 100$$

$$= \frac{12.19 - 19.2}{19.2} \times 100 = 37\%$$

The emission quotas are

$$(EQ)_{i\ \text{Undesignated}} = (E)_{i\ \text{Undesignated}} \times (1 - .37) = .63\ (E)_{i\ \text{Undesignated}}$$

For example,

$$(EQ)_2 = (.63) \times (11{,}890) = 7{,}490 \text{ T/yr. of particulates.}$$

These emission quotas are given in the table . That the air quality at X is 60 $\mu g/m^3$ can be verified as above.

6. A cautionary note must be added to all these alternative quotas. The verification that the computed quota would, in fact, attain and maintain the NAAQS was based on a simple proportional calculation. It would be necessary to verify this using the AQDM model. In addition, it is necessary to verify that these quotas will not produce air quality violations at receptors other than the one studied here.

SOLUTION 8-4. Emission Quota Calculations

Subarea	Emissions (T/yr.)	% Contribution	Uniform Reduction Emission Quota (T/yr.)	Air Quality Impact ($\mu g/m^3$)	Air Quality Impact of 10^4 T/yr. ($\mu g/m^3$)	Equal Air Quality Impact: Emission Quota (T/yr.)	Equal Air Quality Impact: % Reduction	Equal Air Quality Impact Plus 75% Maximum Reduction: Emission Quota (T/yr.)	Growth Subareas and Clean Subareas: Designation	Growth Subareas and Clean Subareas: Emission Quota (T/yr.)
1	14,500	1	8,120	0.8	0.55	42,360	-	41,890	Growth	15,950
2	11,890	3	6,658	2.4	2.02	11,530	3.0	11,060	-	7,490
3	5,160	2	2,890	1.6	3.10	7,520	-	7,050	-	3,250
4	38,700	7	21,672	5.6	1.45	16,070	58.5	15,600	Growth	42,570
5	1,100	1	616	0.8	7.27	3,200	-	2,730	Clean	275
6	3,000	20	1,680	16.0	53.33	437	85.4	750	Clean	750
7	12,300	11	6,888	8.8	7.15	3,260	73.5	2,790	-	7,750
8	2,130	2	1,193	1.6	7.51	3,100	-	2,630	Clean	532
9	9,800	4	5,488	3.2	3.27	7,130	27.2	6,660	-	6,170
10	12,000	4	6,720	3.2	2.67	8,730	27.2	8,260	-	7,560
11	25,000	2	14,000	1.6	0.64	36,410	-	35,940	Growth	27,500
Background		43		34.4						
TOTAL	135,580	100	75,925	80.0		139,747		135,360		119,797

SOLUTION 8-5

Determine possible locations for: (1) 100-T/day source, (2) 10-T/day source.

1. The 100-T/day source cannot be located in County X. The particulate concentration at any point is the sum of two parts:

   Particulate concentration =
   Projected concentration + Contribution from additional source

   The isopleths give the projected concentration. The possible minimum projected concentration is the background level 34 $\mu g/m^3$ and all actual projections are higher than this due to projected source activity. The footprint gives the concentrations from the additional source. The sum of these two must be less than or equal to 60 $\mu g/m^3$. A 45 $\mu g/m^3$ isopleth runs adjacent to the source in the footprint. Thus, considering only background, particulate concentrations near the 100-T/day source would be at least 45 + 34 = 79 $\mu g/m^3$. Since this exceeds 60 $\mu g/m^3$, this large source could not be built.

2. For a 10-T/day source, the concentrations in the footprint are reduced to 1/10 of the indicated values. As a first approximation, the region outside the 0.5 $\mu g/m^3$ isopleth may be taken as representing a negligible concentration. When this isopleth is inside any area of County X within a 60 $\mu g/m^3$ isopleth, a violation of the 60 $\mu g/m^3$ secondary guideline occurs. If the region within the 4.5 $\mu g/m^3$ footprint isopleth enters an area of the county with concentrations above 55 $\mu g/m^3$, a violation occurs. An approximate 55 $\mu g/m^3$ isopleth is sketched in as a dotted line on the isopleth figure.

   By moving the footprint around the existing isopleths subject to these two constraints and marking the source locations, areas where the source might be built can be mapped out. The line of locations where the 10-T/day source would satisfy these air quality constraints is shown in the figure. Areas of the county on the side of this line away from the high concentration locations provide potential sites. Of course, the possible constraints due to the other footprint isopleths must also be considered. Any accurate determination of potential sites will require further detailed evaluation. This footprint process will limit the area to which detailed analysis must be applied.

   The determining constraints along the source line are:

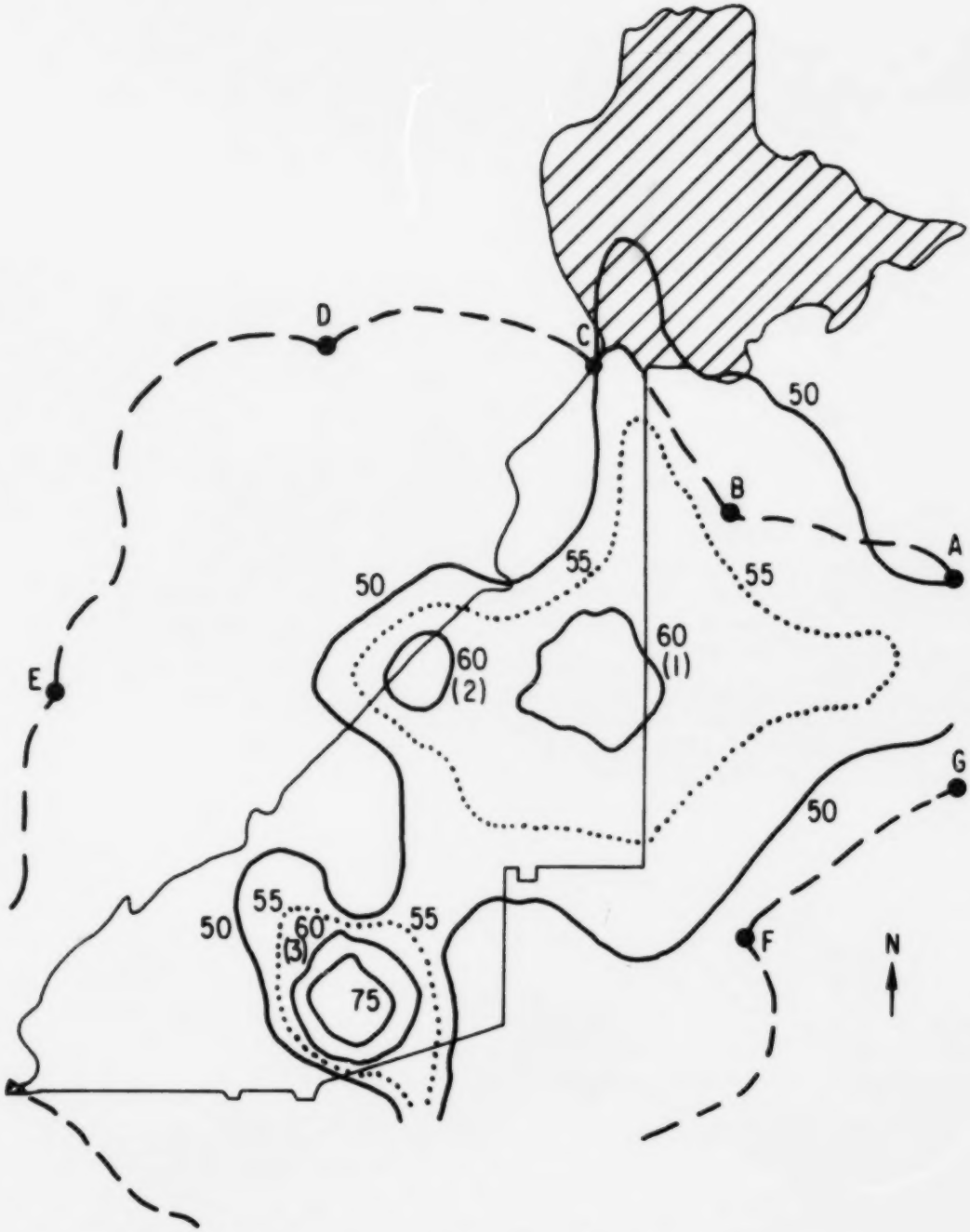
Between Points	Footprint Isopleth	County Isopleth
A, B	0.5	60 (1)
B, C	4.5	55
C, D	0.5	60 (1)
D, E	0.5	60 (2)
E, F	0.5	60 (3)
F (G)	0.5	60 (1)

The region outside this line within County X includes:

The large region in the northern part of the county and

One very small part on the southwestern tip of the county.

These areas are shaded in the isopleth figure. They are areas where detailed study is most likely to show that the 10-T/day source could be located.



SOLUTION 8-5. Locational Possibilities for 10T/day Plant

SOLUTION 9-1

Determine present value costs in constant dollars of two alternatives.

1. Use the portion of Equations 9-3 and 9-4 in brackets to determine the cost factor for each year.

   a. $i = 7\%$ $e = 6\%$

   $(1+i)\ (1+e) = (1.07)\ (1.06) = 1.13$

   $[(1+i)\ (1+e)]^{-t} = (1.13)^{-t}$

   $= 0.8850$ for $t = 1$
   $= 0.5428$ for $t = 5$
   $= 0.2946$ for $t = 10$
   $= 0.0868$ for $t = 20$

   $$\frac{1 - [(1+i)\ (1+e)]^{-t}}{(1+i)\ (1+e) - 1} = 7.0246 \quad \text{for } t = 20$$

   b. $i = 10\%$ $e = 6\%$

   $(1+i)\ (1+e) = (1.10)\ (1.06) = 1.17$

   $[(1+i)\ (1+e)]^{-t} = (1.17)^{-t}$

   $= 0.8547$ for $t = 1$
   $= 0.4561$ for $t = 5$
   $= 0.2080$ for $t = 10$
   $= 0.0433$ for $t = 20$

   $$\frac{1 - [(1+i)\ (1+e)]^{-t}}{(1+i)\ (1+e) - 1} = 5.6276 \quad \text{for } t = 20$$

2. Compute present value constant dollar costs in each year for each alternative.

Alternative	Interest Rate	Year	Cost	X	Cost Factor	=	Present Value in Constant $
I	7%	1	$1,000,000	X	0.8850	=	885,000
		5	$1,000,000	X	0.5428	=	542,800
		20	$1,000,000	X	0.0868	=	86,800
		Operating	$10,000	X	7.0246	=	70,246
					Total		1,584,846
I	10%	1	$1,000,000	X	0.8547	=	854,700
		5	$1,000,000	X	0.4561	=	456,100
		20	$1,000,000	X	0.0433	=	43,300
		Operating	$10,000	X	5.6276	=	56,276
					Total	=	1,410,376

Alternative	Interest Rate	Year	Cost	X	Cost Factor	=	Present Value in Constant $
II	7%	1	$500,000	X	0.8850	=	442,500
		10	$1,000,000	X	0.2946	=	294,600
		20	$2,000,000	X	0.0868	=	173,600
		Operating	$50,000	X	7.0246	=	351,230
					Total		1,261,930
II	10%	1	$500,000	X	0.8547	=	427,350
		10	$1,000,000	X	0.2080	=	208,000
		20	$2,000,000	X	0.0433	=	86,600
		Operating	$50,000	X	5.6276	=	281,380
					Total	=	1,003,330

3. The undiscounted costs for each alternative are:

Alternative I:
$1,000,000 + $1,000,000 + $1,000,000 + 20($10,000) = $3,200,000

Alternative II:
$500,000 + $1,000,000 + $2,000,000 + 20($50,000) = $4,500,000

This might indicate that Alternative I is more desirable. However, when the costs are discounted to current value and corrected for inflation, Alternative II is more desirable at an interest rate of 7% and is substantially more desirable at an interest rate of 10%.